Journal of
Water & Climate Change

 Journal of Water and Climate Change Vol 12 No 7, 3448 doi: 10.2166/wcc.2021.047

Livelihood vulnerability assessments and adaptation strategies to climate change: a case study in Tanguar haor, Sylhet

Farzana Raihan* and Mohammad Melon Hossain
Department of Forestry and Environmental Science, Shahjalal University of Science & Technology, Sylhet 3114, Bangladesh
*Corresponding author. E-mail: fraihan-for@sust.edu

ABSTRACT

Bangladesh is very prone to climate-driven hazards due to its unique geographical location, high population density, and low climate resilience. Therefore, this study addresses the livelihood vulnerabilities and adaptation strategies in response to the climate change issues based on empirical evidence from wetland communities using the livelihood vulnerability index (LVI) in Tanguar haor, located in Sylhet, Bangladesh. The finding shows that people of the study area are switching their formal livelihood activities into alternative sources. Crop diversification, homestead gardening, erosion proofing, and cage aquaculture are commonly used by the studied communities to adapt to climate change impacts. The main driver of vulnerabilities was found to be lack of education, underdeveloped infrastructures, lack of advanced health facilities, and lack of alternative livelihoods during extreme events. Therefore, people living in and around the haor region need special consideration. Overall, the study suggests that policy or institutional arrangements are required to promote the better governance system for local communities to improve their living standard so that they can achieve resilience to the impacts of climate variability and change in this area.

Key words: adaptation, Bangladesh, climate change, haor region, livelihoods vulnerability

HIGHLIGHTS

- Haor communities are naturally linked with seasonal climate fluctuations.
- The livelihood vulnerability index of the haor communities has been focused.
- Livelihoods are vulnerable to socioeconomic conditions and climate variability.
- Community is dealing with disaster using their local knowledge and experiences.
- Intended strategies are essential to enrich the resilience of the poor vulnerable haor communities in Bangladesh.

1. INTRODUCTION

Climate change distresses the whole world. But worst triggers will be those who are already vulnerable. Climate change may affect people differently based on their livelihoods and socioeconomic status (Kabir & Serrao-Neumann 2020). As with other developing countries in South Asia, Bangladesh is the most susceptible country to climate change due to its geographical position, high population density, and poverty, low capacity for adaptation and mitigation (Mirza 2002; Dastagir 2015; Alam *et al.* 2018). According to the World Risk Report 2012, Bangladesh ranked fifth out of 173 countries to natural hazards and the vulnerability of societies (Joarder & Miller 2013). Many studies have been carried out about climate change and its impact on our society and environment. Researcher claimed that frequent natural calamities are the most common issues and affected many districts of Bangladesh (Islam *et al.* 2015). Mostly the riverine households of Bangladesh are at high risk of negative impacts of climate change and experience extreme events such as drought, flood, tropical cyclones, and storm surges every year (Alam *et al.* 2017). These events have killed thousands of people and destroyed homes and livelihoods. The prolonged flood events push thousands of people to become homeless and they lose their homestead and croplands (Saha 2017). Also, in riverine areas of Bangladesh, frequent floods pose a different threat to food security by rice crop damage which ultimately impacts both the country's food security and economy. Due to flash floods, crops are destroyed every year in the northeastern haor region. This situation leads to inflated prices for available food. These price spikes leave the poorest households most vulnerable. As the food systems are dependent on one another, this means that more frequent and more extreme events in one region could disrupt a cluster of food systems – even the country. Although the riverine haor areas are much more fertile land for agricultural production, these areas are relatively poor compared to the rest of the country. There are many reasons attributed to it such as the production of the single crop throughout the year, seasonal unemployment, flood, other natural disasters, lack of communication and other infrastructure facilities, employment opportunities, lack of due attention on the part of the government, and other service providers (Nowreen *et al.* 2013).

People of northern riverine areas are highly exposed to the impacts of climate-driven hazards through rainfall variability and changes in the river flow. Due to the monsoon flooding and deltaic topographical condition, people in the riverine areas are facing riverbank erosion which is the most common destructive disaster in terms of financial loss (Alam *et al.* 2017). Riverbank erosion adversely affected the agricultural sector by changing the local land configuration, soil texture and structure, drainage, and surface conditions and makes the riverine people vulnerable by changing their income and consumption pattern. So, the vulnerable people who are affected by these types of natural hazards persuasively displace the community and thus the occupation and livelihoods (Alam *et al.* 2018). The future of the riverine haor people of Bangladesh relies upon the improvement and disaster management policies of the responsible government and on the regional cooperation and international effort fighting climatic dangers. Therefore, climate change is followed by a significant unpredictability of the new local conditions and vital that initiatives for better climate adaptation.

Though several adaptation plans have undertaken, they were not seemingly effective to identify the major facts and enormity of vulnerability of the community. If we can find the prime aspects of vulnerability and its enormity for a susceptible community, it will be beneficial to measure the degree of sustainability of livelihoods that the community possesses. Scholars revealed that the affected people who are living in vulnerable areas have not enough knowledge to deal with the likely impacts of climate change. But nowadays, most of the households have now become accustomed by taking some steps in different events like floods and heavy rainfall. Therefore, exploring adaptations associated with local-level knowledge is regarded as an important adaptation strategy for people to deal with an extreme climatic event. So far only a few studies have been conducted to identify the impacts of climatic events, the reason of happening such events, adaptation strategies especially adopted by local people, and how it can be mitigated through building local awareness. To date, there have been only a few in-depth studies of livelihood vulnerability assessment. Without recognizing local level vulnerability patterns, it is likely to be least effective to recommend any copying or adaptation mechanism. Through implementing a cohesive and participatory action-research approach, this project explores how rural communities living in disaster-prone areas in Bangladesh respond to increasing incidences of extreme events. Therefore, the objective of this research is to assess the meteorological conditions, people's perceptions regarding vulnerabilities to natural hazards, and their adaptation strategies based on their socioeconomic perspective in Tanguar haor, Sylhet, Bangladesh.

2. METHODOLOGY

2.1. Study area

Tanguar haor is located at the northern outskirt of riverine Bangladesh covering 9,727 ha. It is adjacent to the Indian border and one of the largest haor (river basin) which is part of a wetland of the Surma–Kushiyara river basins (see Figure 1). It is situated in the northeast region relative to natural state between 25.1615° N and 91.0778° E. The ecosystem is most diversified in Tanguar haor. It is not merely ecologically but has also socioeconomic importance for supportive livelihood to around 70,000 people. Around 50% of the area of Tanguar haor is placed in water bodies, followed by 31% of crop land (Islam *et al.* 2014). It comprises 46 villages and around 120 beels (Hossain *et al.* 2017). The swamp forest land of the haor is one more exceptional ecological feature of the haor ecology which acting as a significant role in fish production and functions as a 'mother fishery' for the country (Chowdhury 2010). Since its ecological importance, it has been acknowledged as the second Ramsar site of Bangladesh in 2000 (Sun *et al.* 2017).

2.2. Data collection

Secondary data were collected from sources of different publications, newspapers, and Wikipedia. The climatic data (temperature and rainfall) are collected from the BMD (Bangladesh Meteorological Department). Historical climate change (temperature and rainfall) analysis was done by simple linear regression analysis over the period 1980–2018. The primary data were collected through individual respondent surveys, direct field visits, and focus group discussions (FGDs). A semi-

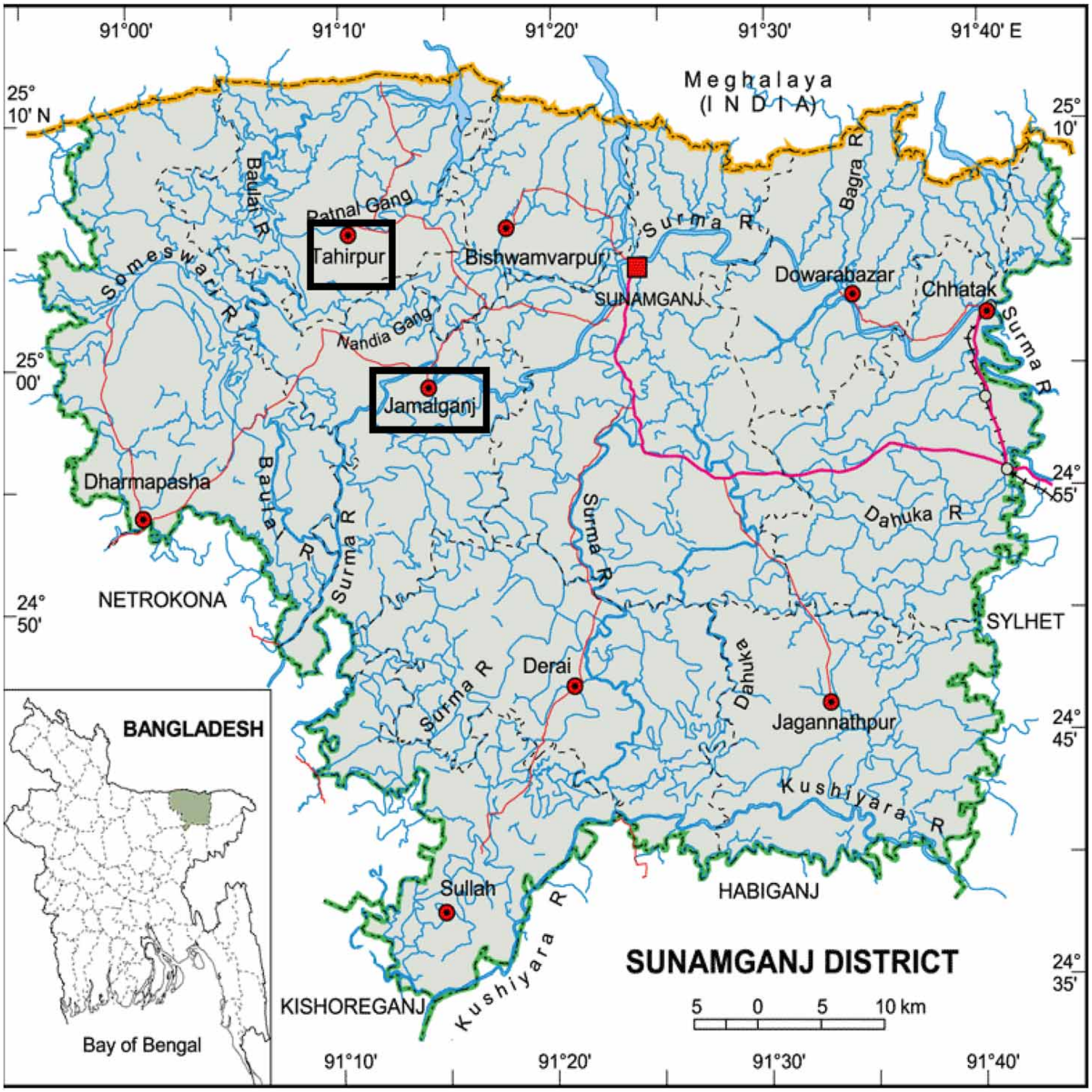

Figure 1 | Location of the study area. Two Upazilas, i.e., Tahirpur and Jamalganj, have been marked from the Sunamgonj district map (modified from LGED 2001).

structured questionnaire was used to collect data on each topic from the head of the households. The data were collected on the livelihood practices, agricultural system, monthly income–expenditure, local awareness, perception of climate change, and natural disasters. They were asked about their socioeconomic condition such as number of family member, their age, gender distribution, educational background, housing condition, occupation, and their income level per month. The impacts of natural hazards on shelter, water supply system, sanitation system, health condition, food habitat, the intensity of livelihood vulnerability, perception of occurrence of various natural disasters were also asked. Through detailed interviews of the respondent, data were collected by using a semi-structured questionnaire. During the field visit, several questions related to climate change adaptation were also asked to the respondents.

2.3. Selection of villages

Tanguar haor, covering an area of 9,727 ha comprises two Upazilas namely Tahirpur and Dharmapasha under Sunamganj district located in the northeast part of Bangladesh. It is very tough, expensive, and time-consuming to carry out research work in two of these Upazilas. In this context, the selection of villages was made because of secondary information based on the level of vulnerability to flooding condition and waterlogging. Areas of study were chosen to recognize the impact of climatic catastrophe and the mechanism of adaptation to these various dangers. Considering all the criteria, Tahirpur and Jamalganj Upazilas were selected purposively because the areas are situated in the 'haor basin'. Then a list of villages was fixed afterwards. Then 10 villages were selected randomly from the list. Five villages were selected from each village. Manik Khila, Dumal, Santospur, Ramshinghpur, and Janjail villages were selected from Tahirpur Upazila, and Fenarbag (central), Fenarbag (west), Vobanipur, Santipur, and Badarpur were selected from Jamalganj Upazila.

2.4. Selection of respondents

Prior to individual respondent data collection, study villages were visited, and an FGD was done to know about the local people condition, locality, and farming system in order to make an appropriate sampling approach. In each FGD, a variety of respondents like local Upazila members, government officials, and development workers were included. A total of four (two from Tahirpur Upazila and two from Jamalganj Upazila) FGDs were done in 10 study villages, and a number of respondents were fixed during the FGDs. Then, data were collected from a total of 120 respondents of the 10 study villages, 10 from each village. The male and female respondents were selected who are young or old age for interview because they are experienced and head of the family.

2.5. Livelihood vulnerability index analysis

The livelihood vulnerability index (LVI) was developed by Hahn *et al.* (2009) for vulnerability assessment of climate change. It has been designed to provide information to the development organizations, policymakers, and public health practitioners to understand climate vulnerability and its related component such as demographic, social, and health (Hahn *et al.* 2009). The LVI uses an evenly balanced weighted approach. This weighting scheme could be adjusted by future users if it is needed. Because each of the subcomponents is measured on a different scale, it was first necessary to standardize each as an index. The LVI includes five major components: sociodemographic profile, livelihood strategies, social networks, climate sensitivity of households (food, water, health, housing, and land tenure), and natural disasters and climate variability. Each major component is comprised of several subcomponents (see Tables 1 and 2). As this method has flexibility, we used more relevant subcomponents in this study based on the literature review and expert opinion. To analyze the index, we have followed four main steps, namely:

Step 1. Transforming measurement units: All the raw data of each subcomponent which was collected through a questionnaire survey was transformed into appropriate standardized measurement units, such as percentages, ratios, and indices.

Step 2. Standardization of subcomponents: It was first necessary to standardize each subcomponent as an index because these were measured on different scales. The equation (Equation (1)) is used for the conversion, which was adapted from that used in the Human Development Index to calculate the life expectancy index, which is the ratio of the difference of the actual life expectancy and a pre-selected minimum, and the range of pre-determined maximum and minimum life expectancy (UNDP 2010):

$$\text{Index}_{s_d} = \frac{S_d - S_{\min}}{S_{\max} - S_{\min}} \quad (1)$$

where S_d is the average value of the subcomponent or indicator value of village d, $S_{\max}$ is the maximum value of subcomponent, and $S_{\min}$ is the minimum value of subcomponent.

Step 3. Averaging of Subcomponents: The standardized scores of each subcomponent were averaged by using the following formula:

$$M_d = \frac{\sum_{i=1}^{n} \text{Index}_{S_{d_i}}}{n} \quad (2)$$

where M_d is one of the seven major components for district d [sociodemographic profile (SDP), livelihood strategies (LS), social networks (SN), health (H), food (F), water (W), housing and land tenure (HLT), or natural disasters and climate

Table 1 | Major and subcomponents comprising the LVI

Major components		Subcomponents	Explanations/assumed functional relationship
Sociodemographic profile		Ratio of uneducated to educated people	Higher value of ratio is more vulnerable
		Percentage of female-headed households	Generally, women are less adaptive people.
		Percentage of female-educated person	Higher percentage reflects more adaptive capacity and less vulnerable.
		Percentage of households where head of the households completed the primary school	Educated households heads are less vulnerable.
Livelihood strategies of the households		Ratio of independent members to dependent members	When in a household dependent members are more, that family is more vulnerable.
		Percentage of households with family members working in different communities	Adaptive capacity can be increased by income diversification.
		Average number of earning members	More numbers are more adaptive
		Average agricultural livelihood diversity index	Less value households are comparatively more adaptive
		Percentage of households of which income per month is below 5,000 or $60	Higher percentage reflects more capacity to adapt
		Percentage of households whose secondary occupation is fishing	Higher percentage expresses less vulnerable and has high capacity to adapt
Social networks		Percentage of households do not receive any warning about flood before it occurred	Communication media are more useful to get information about flood/cyclone/drought before it occurred
Climate sensitivity of households	Food	Average number of livestock they have own	Higher percentage reflects more capacity to adapt
		Average item of livestock they have own	Higher percentage reflects more capacity to adapt
		Percentage of households dependent solely on agricultural land for food	Less percentage expresses less vulnerable
	Health	Average time to hospital facility	Long time reflects more vulnerable
		Percentage of households with family members suffering chronic illness	Lower percentage expresses less vulnerable
		Ratio of chronically ill female members to chronically ill members	The households are more vulnerable when the ratio is high because generally women are less adaptive capacity
	Housing & land tenure	Percentage of households with legal ownership of the land they live on	Higher percentage is more capable and has adaptive capacity
		Percentage of households who are not safe from flood	Higher percentage is more vulnerable and less adaptive capacity
	Water	Average time to get safe water from water sources	Higher percentage expresses more adaptive capacity
		Percentage of households drinking unsafe water (river, pond, or canal water)	Higher percentage indicates less adaptive capacity since the water of pond/river is polluted
Natural disasters		Percentage of households of which any member injured in the flood	The households are less vulnerable whose percentage is low
		Average number of flood affected them	Higher value reflects more vulnerability
		Average number of flood occurred in the last 5 years	More flood events reflect higher exposure
		Average time of last flood stayed/lagged at this area	Long time reflects higher exposure

variability (NDCV)]. $\text{Index}_{S_{d_i}}$ is the ith subcomponent value, belonging to major component M_d for village d. n is the number of subcomponents in each major component.

Step 4. Calculating final LVI score: When values for each of the major components were calculated, then they were averaged using Equation (3) to obtain the final LVI score. The average of each major component was calculated from the number

Table 2 | Categorization of major components into contributing factors from the IPCC vulnerability definition for the calculation of the LVI–IPCC

Group 1: Adaptive capacity	Group 2: Sensitivity	Group 3: Climate exposure
Sociodemographic profile	Food	Natural disasters and climate variability
Livelihood strategies	Health	
Social networks	Water	

of subcomponents of which it was comprised. The LVI is scaled from 0 (least vulnerable) to 0.5 (most vulnerable).

$$LVI_d = \frac{\sum_{i=1}^{7} W_{M_i} M_{d_i}}{\sum_{i=1}^{7} W_{M_i}} \quad (3)$$

where LVI_d is the livelihood vulnerability index for district d, M_{d_i} is the major component for community d indexed by i, and W_{M_i} is the weight of each major component.

2.6. LVI–IPCC calculation

The LVI–IPCC index is an alternative to evaluate LVI by merging the definition of vulnerability corresponding to IPCC. Vulnerability is an action of a process that exposes and susceptible to environmental stimuli and their adaptability to negative impacts (Shah *et al.* 2013). For this analysis, the major components of LVI data were categorized into three groups, these are adaptive capacity, sensitivity, and climate exposure. Table 2 describes the processes of calculating LVI–IPCC. Exposure represents the nature and degree to which a system is subjected to large climate variations. The exposure of this research population is measured by the average number of natural disasters (flood, flash flood, drought, and storm surges) that occurred and reported by the respondent in the last 5 years. Adaptive capacity denotes the ability of a group or individual to deal with the challenges through local knowledge and strategies to make an adjustment. Sensitivity is measured using the facilities of available food, health, and water in the study area. Understanding these components can assist to assess the nature and magnitude of the climate change risk together with the recognition of substantial sources of vulnerability. The LVI–IPCC ranged from -1 (least vulnerable) to $+1$ (most vulnerable) (Hahn *et al.* 2009).

The LVI–IPCC was calculated with the following formula:

$$CF_d = \frac{\sum_{i=1}^{n} W_{m_i} M_{d_i}}{\sum_{1}^{n} W_{m_i}} \quad (4)$$

where CF_d is the IPCC-defined contributing factor (exposure, sensitivity, or adaptive capacity) for community d, M_{d_i} is the major component for community d indexed by i, W_{m_i} is the weight of each major component, and n is the number of major components in each contributing factor.

After calculating the exposure, sensitivity, and adaptive capacity, the following equation was used to calculate LVI–IPCC:

$$LVI - IPCC_d = (e_d - a_d) * S_d \quad (5)$$

where $LVI–IPCC_d$ is the LVI for community d expressed using the IPCC vulnerability framework, e_d is the calculated exposure score for community d (equivalent to the natural disasters and climate variability major component), a_d is the calculated adaptive capacity score for district d (weighted average of the sociodemographic, livelihood strategies, and social network major components), and S_d is the calculated sensitivity score for district d (weighted average of the heath, food, water, and housing and land tenure major component).

2.7. Climate change adaptation strategies

The collected respondent data on the daily livelihood activities, farming system, and indigenous knowledge that are related to climate change adaptation were cross-checked during the field visit and documented in the present study.

3. RESULTS AND DISCUSSION

People living in different riverine areas of Bangladesh have been suffering from recurrent catastrophes which cause large damages every year and ultimately affect the overall livelihood pattern of the local communities. So, understanding local climate, perceptions, and adaptive behavior of household levels bring enhanced insights and information relevant to a policy that helps to address in the face of climate change.

3.1. Historical climate change scenario over 39 years

Rainfall and temperature are two climatic parameters that profile the structure of any socioecological system. In this study, historical changes in temperature and rainfall were evaluated for the Sylhet district, Bangladesh. Meteorological records from this region indicate that temperature has increased significantly ($p = 0.0001$) over the period 1980–2019 (see Figure 2), although there has been no significant trend in mean annual rainfall. A more accelerated temperature change was also observed in the last 30 years (Raihan *et al.* 2015; Rahman & Lateh 2017). Another study reported by Basak *et al.* (2013) also demonstrated the indication of increasing temperature in the northeast region of Bangladesh. The trend of the temperature indices represents that the mean annual maximum temperature is increasing in recent decades with the highest rise in 2014 (35.11 °C). An increasing trend was noted in the mean maximum temperature for the year 1980–1992, i.e., 33.2 °C, and for the years 1993–2005 and 2006–2018 was 33.78 and 34.51 °C, respectively. These statistics revealed that the rise of maximum temperature is higher in recent years (0.73 °C between 1993–2005 and 2006–2018) comparing to previous years (0.58 °C between 1980–1992 and 1993–2005). Khan *et al.* (2019) reported in their study that the average monthly maximum temperature and minimum temperature have increased significantly by 0.35 and 0.16 °C/decade, respectively. Using the trend line equation, Rahman & Lateh (2016) also found that the annual maximum and minimum temperatures have increased from 1971 to 2010. From the last 39 years, the mean annual minimum temperature was found the lowest in 1992 and the highest in 2016. Apart from that, a statistically significant positive trend of mean annual minimum temperature has also been detected equally as the mean annual maximum temperature (see in Figure 3). The mean annual minimum temperatures of 17.04, 17.67, and 18 °C have been detected between the years 1980–1992, 1993–2005, and 2006–2018, respectively, which indicates the gradual rise of mean annual minimum temperature. Hence, it might be claimed that in this region, distinct warming trends were observed, and mostly the maximum temperature has a larger influence on the annual warming.

In contrast to the significant changes in temperature, there is a negative trend in the mean annual rainfall which is statistically insignificant ($p = 0.5$, see in Figure 4). The results also expose fluctuations over decadal changes. Findings demonstrated that a decrease of mean annual rainfall between 1980–1992 (4,350 mm) and 1993–2005 (3,905.85 mm) is detected, whereas an increase between 1993–2005 (3,905.85 mm) and 2006–2018 (4,053.15 mm) is found which is corresponding to the observation of Khan *et al.* (2019). The additional uplifting effect of the Meghalaya plateau could be responsible for the increased rainfall in the post-monsoon season for the northeast of Bangladesh (Shahid 2011; Khan *et al.* 2019). Another possible cause of reducing rainfall might be the warming of the Indian Ocean which possibly declines the land–sea thermal difference over parts of South Asia (Roxy *et al.* 2015).

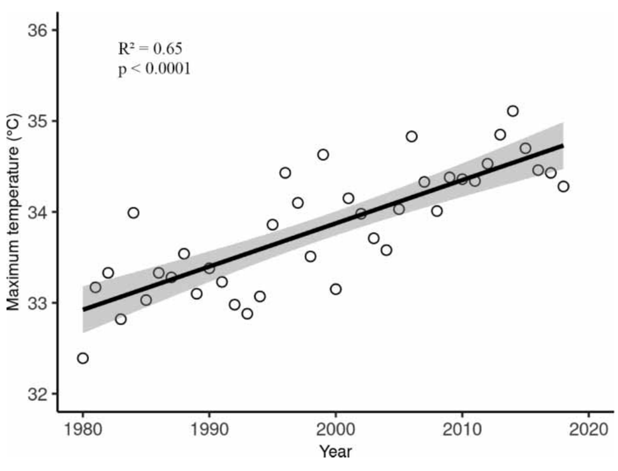

Figure 2 | Annual maximum temperature (°C) changes over the period 1980–2019.

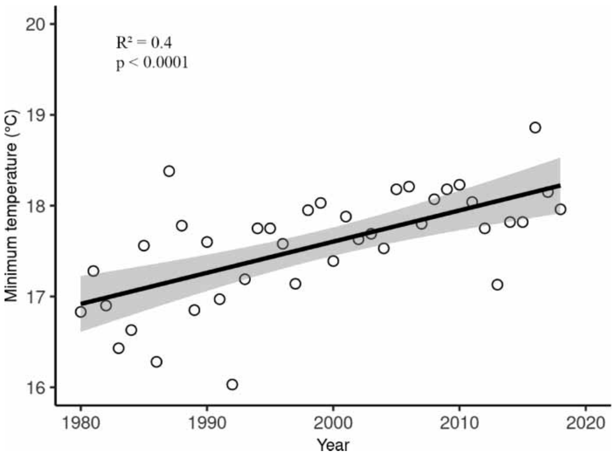

Figure 3 | Annual minimum temperature (°C) changes over the period 1980–2019.

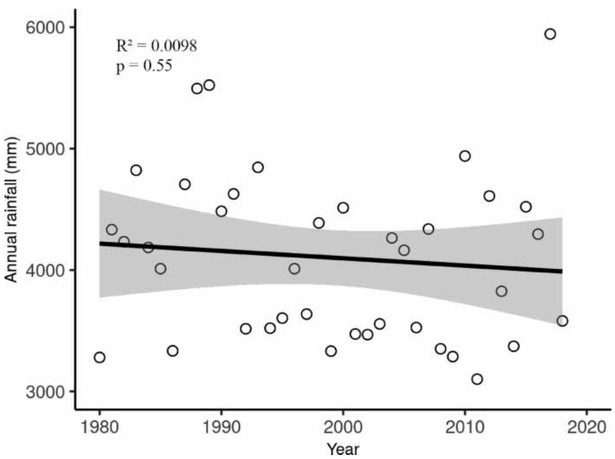

Figure 4 | Annual rainfall (mm) range over the period 1980–2019.

3.2. Comparison of water level flow and extent over the period 2019–2015

Water flow in Tanguar haor comprises mainly of water from the river systems situated south of the Sunamganj district. Water is also received from streams flowing from upstream northern hills in India. Water levels within Tanguar haor regularly rise during wet seasons as water flows from the Surma rivers into the haor (Bagchi *et al.* 2020). The water level of this haor area increased due to the increase of rainfall and water level of Surma river which ultimately experiences flash flood events (Muzaffar & Ahmed 2007). In Tanguar haor, flash flood event occurs frequently when the river water level exceeds the danger level (DL). The Surma at Sumanganj exhibited a fast rise and drop in different periods of the monsoon (see Table 3). In the year 2019, the water level of the river Surma at Sunamganj poured beyond its DL (8.25 m) for 7 days during the monsoon. Recorded results show its highest peak of 8.64 m PWD on 11 July, which was 39 cm above its DL. The maximum water level of Surma at Sunamganj was 8.47 m PWD on 5 July 2018 which was 22 cm above its DL (8.25 m). During the whole monsoon in 2017, the DL of the river Surma at Sunamganj continues for 15 days and recorded its highest peak of 9.19 m PWD on 14 August which was 94 cm above its DL (8.25 m). In 2016, Sumangnaj showed the rapid rise in water levels from mid-April with the abrupt jump some time in May and June with its maximum peak of 9.15 m PWD on 21st July, which was 90 cm above the DL. On 20 August 2015, the water level of Sunamganj flows 83 cm above DL (8.25 m), and the highest peak was 9.08 m PWD. Throughout this year, the water level crossed the DL two times and remained in a total of 31 days. Besides, the Sunamganj district experiences the highest annual average water level anomaly (0.0996 mm) in the year 2017 in Table 3 (Bagchi *et al.* 2020). Exposure of this area may be affected by flash floods that devastate the key production sector (i.e., agriculture) and hence threaten the livelihood of the haor households. According to the

Table 3 | Comparison of water level (in m PWD) over the period 2019–2015

Sl. No.	River	Station	Year	Peak WL (m PWD)	Previously recorded maximum (m PWD)	DL (m PWD)	Days above DL	Annual average water level anomaly (mm)
1	Surma	Sunamganj	2019	8.64	9.75	8.25	7	0.0741
2	Surma	Sunamganj	2018	8.47	9.75	8.25	3	0.0638
3	Surma	Sunamganj	2017	9.19	9.75	8.25	15	0.0996
4	Surma	Sunamganj	2016	9.15	9.46	8.25	9	0.0337
5	Surma	Sunamganj	2015	9.08	9.46	8.25	31	0.0333

Source: Annual Flood Report, FFWC, BWDB. (Flood Forecasting & Warning Centre (FFWC) & Bangladesh Water Development Board (BWDB) 2014)

department of agriculture extension, Tanguar haor has been affected most extensively due to the flash flood of 2017. The total affected area was 30,100 ha, and the total damage of standing crops in the boro field was 18,200 ha. Due to enormous damages of rice production, 33% of the population need to displace. Property loss of population was 65%. Research demonstrated that due to flash floods, 48% of people suffered from a shortage of drinking water. Different water-borne diseases have broken out and trigger the vulnerability. Around 10% of people were affected by diseases because of poor health facilities during the post-disaster period. This perhaps implies that the needy people suffer the hardest time during floods due to inadequate means of protection measures and also the loss of property and income (Parvin *et al.* 2016). Another study by Islam *et al.* (2020) evaluates the risk and resilience level of flash floods and reported that 55% of people of Tahirpur in Tanguar haor have low resilience that renders them more vulnerable. So, the higher the number of floods, the higher the vulnerability and impacts caused by the hazards will be higher also. Accordingly, in future studies, a flood hazard map (intensity and probability of occurrence) along with a flood damage risk map will deliver additional insights. In this study, the exposure to natural disasters to climate change was evaluated by detecting the impacts due to climate variability and change using the respondent perceptions of hazards and coping methods during the last 5 years.

3.3. Perceptions of local communities on changing pattern of climatic impacts

All of the 200 respondents comprising of each village were asked if they understand the changes in temperature, rainfall, and duration of the summer season, rainy season, winter season, and the resultant impacts or the changing pattern of climatic impacts they had experienced within the last 5 years or not. Figure 5 presents the respondents' perception regarding climate changes in the study area. During field investigations, it is found that more than 87% of the respondents were not concerned about climate change and its impacts on the human and nonhuman environment. Most of them believed that the natural events are coming from God and, hence, it cannot be dodged; mostly God will determine who would suffer and who would be safe. The local respondent opinion is consistent with the findings of Kamal *et al.* (2018) and Anik & Khan (2012). Though the results revealed that none of the respondents had any prior idea about climate change, but they were able to respond to the questions when the terminology was made understood to them. Respondents perceived that both the intensity of hazards and vulnerability of the people have increased considerably over the last few decades. They reported that the heat intensity has increased immensely during summer and winter, which does not occur timely over the last 5 years (Figure 6). Since most of the people of the haor region live on low-lying land, the income source of both the farmers and fishermen are disturbed and often destroyed. The study areas face significant flood and riverbank erosion hazards. Besides, due to the floods and drought in the dry season, most of the farmers can cultivate rice just once a year. Kamal *et al.* (2018) also reported in their findings that they primarily rely on dry season boro rice crops as their primary source of income.

3.4. LVI analysis

3.4.1. Model 01: LVI

The actual and standardized values along with maximum and minimum values of subcomponents of five villages are presented in Table 4. The aggregate score (Model 01) suggests that Tahirpur is more vulnerable than Jamalganj due to the higher LVI values. Results reveal that Tahirpur is more vulnerable to adaptive capacity in terms of sociodemographic profile, livelihood strategies, and social network components compared to Jamalgonj (see Table 5). The sociodemographic major component was composed of three subcomponents (percentage of female-headed households, the average age of household

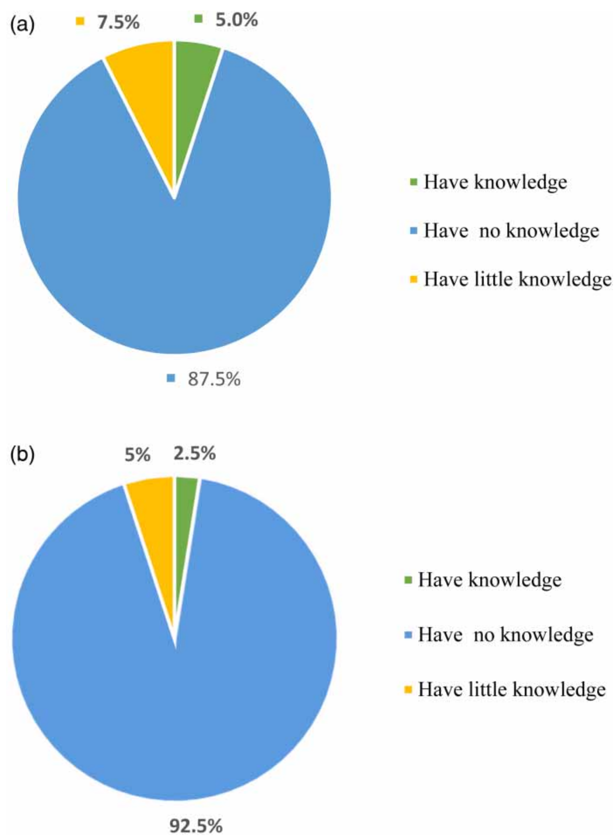

Figure 5 | Percentage of household's perceptions related to climate change at Jamalgonj (a) and Tahirpur (b).

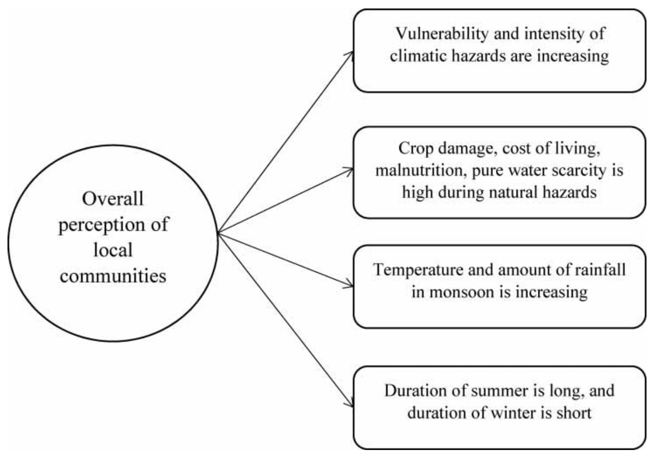

Figure 6 | Overall perception of local communities on different climatic events in the last 5 years.

head, and percentage of households have no education). It represents that the dependency ratio is higher in Tahirpur (0.280). In the case of livelihood components, most households (87%) stated that they have been engaged in agriculture as a source of income in Tahirpur, whereas the case is a little different in Jamalgonj. Around 92% of people rely on fishing. The social network indicators reflect that households do not get training on adaptation or local government assistance. According to the respondent, they did not receive any early warning about the flood.

In the case of sensitivity, both villages show an almost similar LVI score. Findings of overall food vulnerability scores demonstrate nearly similar outcomes such as in Tahirpur 0.396 and Jamalgonj 0.398. Households of Tahirpur reported a

Table 4 | Maximum and minimum subcomponent values for two Upazilas

Subcomponents	Unit	Maximum	Minimum	Tahirpur AV	Tahirpur SV	Jamalganj AV	Jamalganj SV
Ratio of uneducated to educated people	Ratio	5	0	1.106	0.221	1.083	0.217
Percentage of female headed households	%	100	0	12.500	0.125	5.000	0.050
Percentage of female educated persons	%	100	0	25.000	0.250	25.250	0.253
Percentage of households where head of the households completed primary school	%	100	0	52.500	0.525	35.000	0.350
Ratio of independent members to dependent members	Ratio	5	0	0.507	0.101	0.550	0.110
Percentage of households with family members working in different communities	%	100	0	40.000	0.400	25.000	0.250
Average number of earning members		4	1	1.375	0.125	1.500	0.167
Average agricultural livelihood diversity index		1	0.2	0.265	0.081	0.281	0.101
Percentage of households of which income per month is below 5,000 or $60	%	100	0	15.000	0.150	2.500	0.025
Percentage of households whose secondary occupation is fishing	%	100	0	87.500	0.875	92.500	0.925
Percentage of households do not receive any warning about flood before it occurred	%	100	0	5.000	0.050	2.500	0.025
Average number of livestock they own		57	0	2.200	0.039	4.875	0.086
Average item of livestock they own		3	0	0.975	0.325	0.925	0.308
Percentage of households dependent solely on agricultural land for food	%	100	0	82.500	0.825	80.000	0.800
Average time to hospital facility	Minute	160	90	143.750	0.768	106.500	0.236
Percentage of households with family members suffering chronic illness	%	100	0	28.342	0.283	26.645	0.266
Ratio of chronically ill female members to chronically ill members	Ratio	1	0	0.650	0.650	0.540	0.540
Percentage of households with legal ownership of the land they live on	%	100	0	100.000	1.000	100.000	1.000
Percentage of households who are not safe from flood	%	100	0	100.000	1.000	100.000	1.000
Average time to get safe water from water sources	Minute	20	2	7.850	0.325	7.850	0.325
Percentage of households drinking unsafe water (river, pond, or canal water)	%	100	0	5.000	0.050	17.500	0.175
Percentage of households of which any member injured in the flood	%	100	0	38.672	0.387	36.730	0.367
Average number of floods affected them		4	1	2.275	0.425	2.125	0.375
Average number of floods in the last 5 years		5	1	3.475	0.619	3.225	0.556
Average time of last flood stayed/lagged at this area	Day	45	15	27.500	0.417	25.375	0.346

longer average time to get health facilities and show a higher LVI score (0.567) than Jamalgonj (0.347). Households of Tahirpur stated that they face significant malnutrition and diseases during the disaster period and suffering from chronic illness. It is found that Jamalgonj (LVI = 0.250) is more vulnerable than Tahirpur (LVI = 0.188) in terms of the water resources component. Households of Jamalgonj reported using unsafe water for their daily needs and suffering from recurrent waterborne diseases. This could be due to their low level of education and awareness and longer traveling time to reach safe water sources. The vulnerability of housing and land tenure (1.00) is the same for both Upazilas. In terms of land ownership, many households lacked a basic form of land tenure. Therefore, due to limited property rights and housing conditions (fundamentally raw house made of bamboo, mud, and straw), living in Tanguar haor is also very strenuous (Haque & Kazal 2008). Roy (2010) stated that in the Jamalgonj area, 83% of fishers' house structures are Kacha as they use bamboo for roofing materials and only 17% are semi-paca (floor and wall made of by bricks and roof made of wooden cover). Based on the average reported number of floods that have occurred in the last 5 years, Tahirpur (0.46) has the highest score compared to Jamalgonj (0.41).

Table 5 | LVI values of major components for two Upazilas

Subcomponents	Major Components	Tahirpur	Jamalganj
Ratio of uneducated to educated people	Socio-demographic profile	0.2800	0.2170
Percentage of female headed households			
Percentage of female educated person			
Percentage of households where head of the households completed the primary school			
Ratio of independent members to dependent members	Livelihood strategies of the households	0.2890	0.2630
Percentage of households with family members working in different communities			
Average number of earning members			
Average agricultural livelihood diversity index			
Percentage of households of which income per month is below 5,000 or $60			
Percentage of households whose secondary occupation is fishing			
Percentge of households do not receive any warning about flood before it occurred	Social networks	0.0500	0.0250
Average number of livestock they own	Food	0.3960	0.3980
Average item of livestocks they own			
Percentage of households dependent solely on agricultural land for food			
Average time to hospital facility	Health	0.5670	0.3470
Percentage of households with family members suffering chronic illness			
Ratio of chronically ill female members to chronically ill members			
Percentage of households with legal ownership of the land they live on	Housing & land tenure	1.0000	1.0000
Percentage of households who are not safe from flood			
Average time to get safe water from water sources	Water	0.1880	0.2500
Percentage of households drinking unsafe water (river, pond, or canal water)			
Percentage of households of which any member injured in the flood	Natural disasters	0.4620	0.4110
Average number of flood affected them			
Average number of flood occurred in the last 5 years			
Average time of last flood stayed/lagged at this area			
LVI		0.404	0.364

Floods induced exposure are among the greatest devastating natural disaster in Tanguar haor and cost many lives every year. The findings of the study revealed almost parallel vulnerability scores for the natural disaster component, based upon the average number of reported floods or flash floods at Tahirpur (3.4) and Jamalgonj (3.2) (see Table 4). Understanding how these components and indicators influence the vulnerability of livelihoods, we have set out some questions. In response to the questions related to exposure (natural disaster and climate variability), the households of these two Upazilas conveyed that they do not receive a warning before any disaster which largely affects the livelihood pattern of the people residing in these areas. Regarding the constraints in mitigating flood risks, households reported that 5% of people in Tahirpur and 2.5% in Jamalgonj did not receive any early warning systems due to lack of proper infrastructure and primitive broadcasting system. They reported that due to poor warning systems they could not get adequate time for safety measures to protect themselves and their livelihoods from flood risks. Kamal *et al.* (2018) stated similar findings that only 7.5% of respondents had access to prevailing weather forecasting and attempt to make required arrangements for the impending flood. Furthermore, nearly 38% of the total respondent reported acute injury or death because of the most severe natural disaster. The effect of the devastating scenario of the climatic event (e.g., flash flood, heavy rainfall, river erosion, cyclone, and drought) on every aspect of socioeconomic life at Tanguar haor is also observed by Rahaman *et al.* 2019. Regarding health facilities, households from

Tahirpur (28.3%) and Jamalgonj (26.6%) reported longer average time to get health facilities and experienced the greatest incidence of chronic illnesses due to the shortage of advanced medication facilities during the flooding period. All villages in this study area shared almost a similar degree of vulnerability to natural disasters and climate variability, since these villages belong to the same geographical area. The results of these two Upazilas for major components are presented in the spider diagram (see Figure 7).

3.4.2. Model 02: LVI–IPCC

The LVI–IPCC analysis produced a similar result with LVI analysis within the range from −1 to +1. According to the LVI–IPCC analysis, people of Tahirpur Upazila (0.137) are more vulnerable than Jamalganj Upazila (0.121). A vulnerability spider triangle diagram shows the scores for adaptive capacity, exposures, and sensitivity for Tahirpur and Jamalganj Upazilas (see Figure 8). Results from Model 02 suggested that the two communities shared a very similar degree of vulnerability. The model however suggested that Tahirpur is more vulnerable than Jamalganj in terms of exposure, adaptive capacity, and sensitivity. Tahirpur was more exposed to natural disasters and climate variability (0.46); on the other hand, Jamalgonj was less exposed to natural disasters and climate variability (0.41). The adaptive capacity of Tahirpur (0.21) is greater than Jamalganj (0.17), and the climate sensitivity of households of Tahirpur is 0.54, which is also greater than Jamalganj (see Table 6).

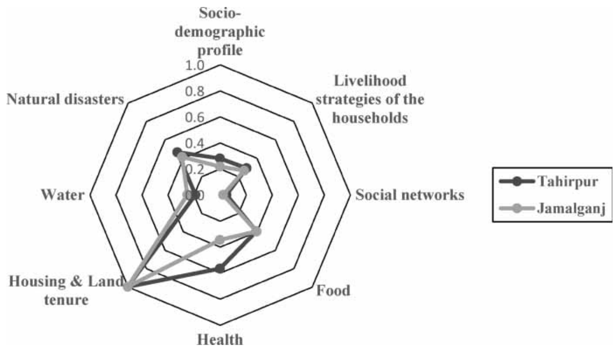

Figure 7 | LVI values of major components for Tahirpur and Jamalganj Upazila (0 = least vulnerable and 0.5 = most vulnerable).

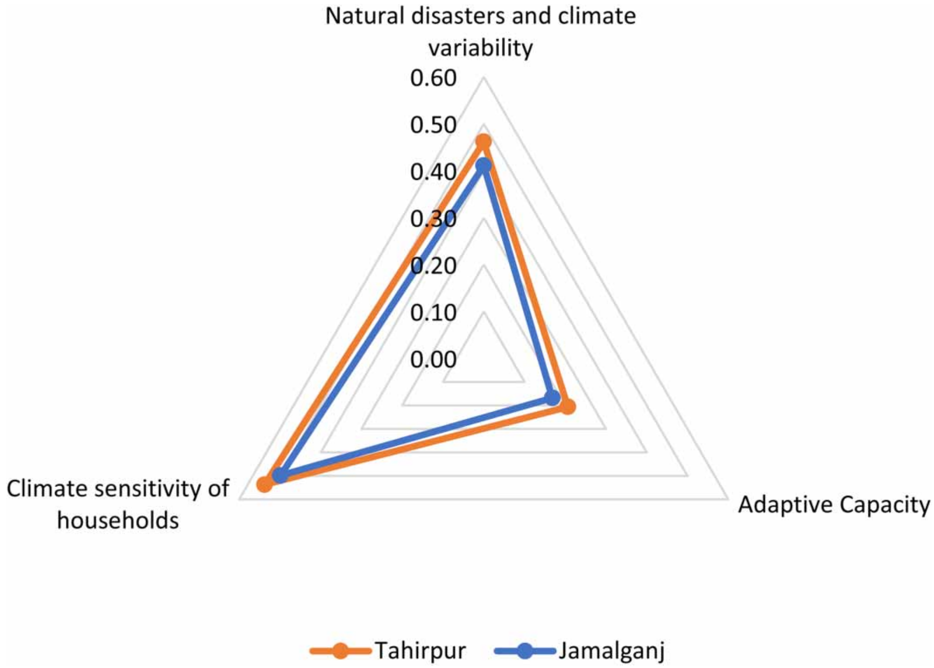

Figure 8 | Triangle diagram of the contributing factors of the LVI–IPCC ranged from −1 (least vulnerable) to +1 (most vulnerable).

Table 6 | LVI–IPCC contributing factor calculation for six villages

	Tahirpur	Jamalganj
Natural disasters and climate variability	0.46	0.41
Adaptive capacity	0.21	0.17
Climate sensitivity of households	0.54	0.50
LVI–IPCC	0.137	0.121

3.5. Identified adaptation strategies in and along with Tanguor haor

Tanguar haor is the distant and backbreaking places of Bangladesh. Traditionally, people of Tanguar haor are communally and structurally downgraded inside and outside of their homes. Communication to major cities is narrow due to the economic condition of the people and behindhand infrastructure. Therefore, the people of Tanguar haor commence various coping methods using their capabilities, resources, familiarity, and their surrounding environment. As the people living in haor areas faced many challenges in their daily life, they preferred to make their household areas slightly above the water level. So, the household areas could hardly affect by flashflood during the rainy season. Kamal *et al.* (2018) reported in their study that flashflood causes huge crop damage (~800,000 t Boro rice; worth the US $450 million) and brings immense danger to the haor people particularly those who work as sharecroppers or landless laborers. The result of the study showed that some respondents were highly cautious about the flood and did not want to lose their crops and preferred to homestead gardening. People of Tahirpur and Jamalganj Upazilas are constructed with various infrastructures to protect themselves from natural hazards. After any hazards, they built a bamboo bridge (Sako) or brick bridge on the road, a water dam to reserve water for the dry season, and two or more storeyed buildings for education in the time of flood. Anik & Khan (2012) also reported in their studies that the people of the northeastern region tried to adapt themselves to climate change by introducing various adaptation strategies such as crop diversification, duck rearing, floating garden, and construction of embankments by their knowledge.

Rarely flashflood arises early in the haor areas so that people could not get time to harvest their crops which results in food scarcity and high price and threats to local livelihood. To ensure food security, weather forecasting assisted them in controlling and timing of plants. Also, haor people allow a single crop throughout a year; therefore, the recurrent unemployment problem is very critical here (Haque & Kazal 2008; Kamal *et al.* 2018; Rahaman *et al.* 2019). But the situation was somewhat different in Tahirpur and Jamalganj. As the haor allows a single crop throughout a year, most farmers were interested in other crops along with cereal crops. Since climate change is affecting the sowing and harvesting time of crops, they prefer to cultivate diversified crops in their agricultural fields. Nowadays, people changing their crop production. They are producing varieties of crops like mung, bean, lentil, linseed, oilseed, potato, spices, pumpkin, corns, and onion, ginger, and garlic with the help of the PROTIC project. Pest outbreak is a great problem in these areas. To get rid of this problem, farmers used various pesticides, though it has a huge environmental impact. Most of the respondents said that the changes in rainfall, raising the temperature, and shifts in time of seasonal onset were the main causes of frequent outbreaks of pests and diseases.

In our study, about 87.5% of Tahirpur and 92.5% of Jamalganj villagers' secondary occupations are fishing. But due to climate change or uneven climate variability, they are changing their fishing location and fishing technique. The common fishing practice in the study areas during the waterlogging period was cage aquaculture. According to them, the earlier species of fish are no longer available. In our study, they are rearing various types of domestic animals like cows, hens, and ducks. The average number of livestock they own is 2.2 for Tahirpur and 4.88 for Jamalganj Upazila, and the average number of livestock items is 0.975 and 0.925, respectively, for Tahirpur and Jamalganj. But the maximum item of livestock for both Upazila is 3. In Tanguar haor, people cannot switch their formal livelihood activities into alternative sources. About 30% of the total respondents are getting 1,500–3,000 Takas per month and nearly 39% are getting 3,000–5,000 Takas as a day labor per month (Haque & Kazal 2008), but in this study, Tahirpur was found economically vulnerable as most workers get more or less 5,000 Takas per month for working in agricultural land and fisheries, whereas people at Jamalganj found financially healthy because the rate of workers who were getting below 5,000 Takas is 2.5% per month. But the area is flood-prone and often struck by flash floods which makes them more vulnerable. Therefore, improving socioeconomic conditions may reduce vulnerability and enhance their adaptive capacity (Sebesvari *et al.* 2016). Skill development training for poor people could be an effective way during seasonal unemployment. Beside developing communication networks, constructing infrastructure and access to organizations for participation can diversify their livelihood and create income opportunities which in turn enhance their resilience. Vittal *et al.* (2020) argued that hydroclimatic hazard's have the most significant role in enhancing risk rather than the social vulnerability (SoV). As a result, focusing the magnitude of hazard and vulnerability in the increasing risk region, policymakers should emphasize individual resilience with an economic capable risk reduction plan.

4. CONCLUSION

In this paper, participants' view and perception of the changing climate were also confirmed by the evidence from temperature and rainfall data analysis. Results indicate that the area has been experiencing seasonal fluctuations over the past 39 years. We found that the causal factors (exposure, sensitivity, and adaptive capacity) independently present variations in their indices for Tahirpur and Jamagonj Upazilas, and no major variation is observed for the total livelihood index. Local livelihoods of the communities were vulnerable with regard to sociodemographic profile, access to food, health, and climate variability. Various factors, such as geographical isolation, lack of education, underdeveloped infrastructures, lack of advanced health facilities, lack of awareness, lack of support from local government, and lack of alternative livelihood during extreme events, had made the community more vulnerable to climate change. Households with low levels of human, physical, natural, financial, and social capitals were found to have limited adaptive capacity to meet the challenges during the disaster periods. Strengthening and improving the indicators identified in this paper could help to reduce the livelihood vulnerability of these two Upazilas. Government and nongovernment organizations should take several initiatives like training for income-generating activities, credit or loan facilities should be provided with ease or at a lower rate of interest that can help them to establish various agro-based industries, fisheries, and other sectors for the diversification of their livelihood options. They should provide an educational program to increase awareness regarding the natural disaster, early warning signs to the community members in making farming decisions, and give empowerment to the women to take a prominent role in climate adaptation strategies. However, due to lack of proper data on individual component, it was not possible for us to compare the ratio of each indicator's response on vulnerability. Future research should be undertaken based on this.

ACKNOWLEDGEMENT

In terms of financial aid, we are thankful to the SUST (Shahjalal University of Science and Technology), Sylhet, Bangladesh, Research Centre. We are particularly indebted to Md. Abu Sayed Arfin Khan, Associate Professor, Department of Forestry and Environmental Science, SUST regarding his assistance during data interpretation.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

REFERENCES

Alam, G. M., Alam, K. & Mushtaq, S. 2017 Climate change perceptions and local adaptation strategies of hazard-prone rural households in Bangladesh. *Climate Risk Management* **17**, 52–63.

Alam, G. M., Alam, K., Mushtaq, S. & Leal Filho, W. 2018 How do climate change and associated hazards impact on the resilience of riparian rural communities in Bangladesh? Policy implications for livelihood development. *Environmental Science & Policy* **84**, 7–18.

Anik, S. I. & Khan, M. A. S. A. 2012 Climate change adaptation through local knowledge in the north eastern region of Bangladesh. *Mitigation and Adaptation Strategies for Global Change* **17**, 879–896.

Bagchi, R., Miah, M. A., Hazra, P., Hasan, R., Mondal, H. S. & Paul, S. K. 2020 Exploring the effect of rainfall variability and water extent in Tanguar Haor, Sunamganj. *Australian Journal of Engineering and Innovative Technology* **2** (4), 66–76. https://doi.org/10.34104/ajeit.020.066076.

Basak, J. K., Titumir, R. A. M. & Dey, N. C. 2013 Climate change in Bangladesh: a historical analysis of temperature and rainfall data. *Journal of Environment* **2**, 41–46.

Chowdhury, A. H. 2010 The state of Community Based Sustainable Management of Tanguar Haor, What measures are to be taken? In: *16th Annual International Sustainable Development Research Conference* University of Hongkong, Hong Kong.

Dastagir, M. R. 2015 Modeling recent climate change induced extreme events in Bangladesh: a review. *Weather and Climate Extremes* **7**, 49–60.

Flood Forecasting & Warning Centre (FFWC) & Bangladesh Water Development Board (BWDB) 2014 *Annual Flood Report 2016*. Bangladesh Water Development Board, Dhaka.

Hahn, M. B., Riederer, A. M. & Foster, S. O. 2009 The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change: a case study in Mozambique. *Global Environmental Change* **19** (1), 74–88. https://doi.org/10.1016/j.gloenvcha.2008.11.002.

Haque, A. K. E. & Kazal, M. H. 2008 *Rich Resources, Poor People The Paradox of Living in Tanguar Haor*.

Hossain, S., Nayeem, A. A. & Majumder, A. K. 2017 Impact of flash flood on agriculture land in Tanguar Haor Basin. *International Journal of Research in Environmental Science* **3** (4), 42–45. https://doi.org/10.20431/2454-9444.0304007.

Islam, m., Hossain, m., Hoque, m., Tusher, t. & Kabir, M. 2014 Study on natural resource management in relation with socio-economic status at Tanguar haor in Sunamgonj district of Bangladesh. *Bangladesh Journal of Environmental Science* **26**, 59–66.

Islam, M. S., Sultana, S., Saifunnahar, M. & Miah, M. A. 2015 Adaptation of char livelihood in flood and river erosion areas through indigenous practice: a study on Bhuapur riverine area in Tangail. *Journal of Environmental Science and Natural Resources* **7** (1), 13–19.

Islam, M. R., Babu, M. A. H., Uddin, M. J., Khatun, M. L. & Islam, M. S. 2020 Investigating the risk and resilience of flash flood in Sunamgonj haor region of Bangladesh. *International Journal of Agricultural Research, Innovation and Technology* **10** (2), 47–53.

Joarder, M. A. M. & Miller, P. W. 2013 Factors affecting whether environmental migration is temporary or permanent: evidence from Bangladesh. *Global Environmental Change* **23**, 1511–1524.

Kabir, M. E. & Serrao-Neumann, S. 2020 Climate change effects on people's livelihood. In: *Climate Action. Encyclopedia of the UN Sustainable Development Goals* (Filho W., L., Azul, A. M., Brandli, L., Özuyar, P. G. & Wall, T., eds). Springer, Cham.

Kamal, A. M., Shamsudduha, M., Ahmed, B., Hassan, S. K., Islam, M. S., Kelman, I. & Fordham, M. 2018 Resilience to flash floods in wetland communities of northeastern Bangladesh. *International Journal of Disaster Risk Reduction* **31**, 478–488.

Khan, M. H. R., Rahman, A., Luo, C., Kumar, S., Islam, G. A. & Hossain, M. A. 2019 Detection of changes and trends in climatic variables in Bangladesh during 1988–2017. *Heliyon* **5** (3), e01268.

Local Government Engineering Department (LGED) 2001 *Annual Report*. LGED, Dhaka.

Mirza, M. M. Q. 2002 Global warming and changes in the probability of occurrence of floods in Bangladesh and implications. *Global Environmental Change* **12**, 127–138.

Muzaffar, S. B. & Ahmed, F. A. 2007 The effects of the flood cycle on the diversity and composition of the phytoplankton community of a seasonally flooded Ramsar wetland in Bangladesh. *Wetlands Ecology and Management* **15** (2), 81–93.

Nowreen, S., Murshed, S. B., Islam, A. K. M. S. & Bhaskaran, B. 2013 *Change of Future Climate Extremes for the Haor Basin Area of Bangladesh*.

Parvin, G. A., Shimi, A. C., Shaw, R. & Biswas, C. 2016 Flood in a changing climate: the impact on livelihood and how the rural poor cope in Bangladesh. *Climate* **4** (4), 60.

Rahman, M. R. & Lateh, H. 2016 Spatio-temporal analysis of warming in Bangladesh using recent observed temperature data and GIS. *Climate Dynamics* **46**, 2943–2960.

Rahman, M. R. & Lateh, H. 2017 Climate change in Bangladesh: a spatio-temporal analysis and simulation of recent temperature and rainfall data using GIS and time series analysis model. *Theoretical and Applied Climatology* **128**, 27–41.

Rahaman, M. M., Sajib, K. I. & Alam, I. 2019 Impacts of climate change on the livelihoods of the people in Tanguar Haor, Bangladesh. *Journal of Water Resource Engineering and Management* **3** (1), 1–9.

Raihan, F., Li, G. & Harrison, S. P. 2015 Detection of recent changes in climate using meteorological data from south-eastern Bangladesh. *J. Climatol. Weather Forecast.* **3** (1), 137.

Roxy, M. K., Ritika, K., Terray, P., Murtugudde, R., Ashok, K. & Goswami, B. 2015 Drying of Indian subcontinent by rapid Indian Ocean warming and a weakening land-sea thermal gradient. *Nature Communications* **6**, 1–10.

Roy, K. 2010 *Fish Biodiversity and the Livelihoods of the Fishing Community in Pagnar Haor under Jamalganj Upazila in Sunamganj District*. MS Thesis, Department of Aquaculture, Bangladesh Agricultural *(unpublished)*.

Saha, S. K. 2017 Cyclone Aila, livelihood stress, and migration: empirical evidence from coastal Bangladesh. *Disasters* **41**, 505–526.

Sebesvari, Z., Renaud, F. G., Haas, S., Tessler, Z., Hagenlocher, M., Kloos, J., Szabo, S., Tejedor, A. & Kuenzer, C. 2016 A review of vulnerability indicators for deltaic social–ecological systems. *Sustainability Science* **11**, 575–590.

Shah, K. U., Dulal, H. B., Johnson, C. & Baptiste, A. 2013 Understanding livelihood vulnerability to climate change: applying the livelihood vulnerability index in Trinidad and Tobago. *Geoforum* **47**, 125–137. https://doi.org/10.1016/j.geoforum.2013.04.004.

Shahid, S. 2011 Trends in extreme rainfall events of Bangladesh. *Theoretical and Applied Climatology* **104**, 489–499.

Sun, C., Zhen, L. & Miah, M. G. 2017 Comparison of the ecosystem services provided by China's Poyang Lake wetland and Bangladesh's Tanguar Haor wetland. *Ecosystem Services* **26**, 411–421.

UNDP 2010 *Climate Change Adaptation Strategy and Programme of Action for the Palestinian Authority*. Available from: http://eprints.lse.ac.uk/30777.

Vittal, H., Karmakar, S., Ghosh, S. & Murtugudde, R. 2020 A comprehensive India-wide social vulnerability analysis: highlighting its influence on hydro-climatic risk. *Environmental Research Letters* **15** (1), 014005.

First received 14 February 2021; accepted in revised form 19 July 2021. Available online 9 August 2021