Ann. Bangladesh Agric. (2022) 26 (1) : 61-73 *ISSN 1025-482X (Print)*
www.doi.org/10.3329/aba.v26i1.67019 04 *2521-5477 (Online)*

IMPACT OF FLASH FLOODS ON AGRI-BASED LIVELIHOODS IN SYLHET HAOR BASIN

N. Akter[1], M. R. Islam[1*], M. A. Karim[1], M. G. Miah[2] and M. M. Rahman[3]

Abstract

Bangladesh is most vulnerable to natural disasters and climate change. Over the past few decades, flash floods have frequently affected the livelihood of people in the Sylhet Haor Basin. This study highlights the causes of increased flash floods, their impact on farming practices and livelihoods, and possible solutions to flash flood risk in the Sylhet Haor Basin. Data were collected using a pre-tested structured questionnaire from randomly selected 298 Haor farmers in high and moderately vulnerable flash flood zones across the Haor region during November 2021 and April 2022. In moderately vulnerable areas, the lack of river and canal dredging was the main factor contributing to flash flood deterioration. Index scores and ranks revealed that flash floods most severely affect the primary production sector (agriculture) and threaten the lives and livelihoods of the local populace in high- and moderately flood-prone areas. After the severe flash flood, farmers were forced to turn to other occupations instead of agriculture for their livelihood. To reduce the impact of flash floods on particular features or entire wetlands, most farmers preferred the construction of embankments over sandbags, concrete or stone dams, submergible embankments, and rubber dams. For flash flood risk management, farmers in high- and moderately flash flood-vulnerable areas emphasize the construction of higher dams and embankments and the installation of more flood barriers (dams/embankments). The concerned flash flood management agencies could incorporate the key findings of this study while formulating risk mitigation strategies for the Sylhet Haor Basin.

Keywords: Flash flood, Sylhet Haor Basin, livelihood, risk management.

Introduction

Sylhet Haor Basin in northeastern Bangladesh comprises a variety of wetland ecosystems, including rivers, streams, and irrigation canals, and a vast area of plain lands that are periodically inundated (Rahaman *et al.,* 2022). Flash flooding is one of the most recurring natural disasters in the Basin (Adnan *et al.,* 2019). A flash flood is defined by a sudden dam failure, mudslides, high discharge at basin exits, extremely high precipitation in a brief period, and abrupt, rapid flooding of low-lying areas (Khosravi *et al.,* 2018). It occurs suddenly and is brought on by heavy rainfall in the upstream catchment of the Meghalaya, Barak, and Tripura Basins of

[1]Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh. [2]Department of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh. [3]Department of Soil Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh. *Corresponding author: rafiarib@yahoo.com

India (Recanatesi *et al.,* 2017). Flash flooding is generally intense during the pre-monsoon season between mid-April and May (Nowreen *et al.,* 2015).

The natural-resource-based farming systems in the Haor support livelihoods through agriculture, fisheries, livestock, and poultry production activities (Islam *et al.,* 2014; Uddin *et al.,* 2019). However, single-crop cultivation, which is dominantly boro rice, and relevant activities are the prime income sources for Haor households. Flash floods frequently cause enormous damage to rice crops just before harvest, usually in April or May. They usually inundate low-lying floodplain lands, damage infrastructure, and submerge crops, resulting in the loss of lives, property, and income (Talukder *et al.,* 2011). An average of more than 4% of the total farmed area was destroyed by flash floods between 1993 and 2010 (CEGIS, 2012). In early 2017, flash floods severely affected nearly one million households and damaged 450 million USD worth of rice crops (Kamal *et al.,* 2018). In the last week of April 2022, there was a devastating flash flood that affected an estimated 7.2 million people and damaged 7,730 ha of boro rice in the Sunamganj, Sylhet, and Habiganj districts (Islam and Chowdhury, 2022). The Basin is experiencing an increase in flash flood damage as a result of social and economic development (Kamruzzaman and Shaw, 2018). Nowadays, farmers are unable to anticipate flash floods due to the construction of various water control structures upstream, the siltation of river beds, and the alteration in river flow. This unpredictable nature of flash floods in the Haor area makes livelihoods more vulnerable (Baten *et al.,* 2018).

Dealing with a flash flood is quite challenging because it has a very short lead-time and is extremely difficult to prevent (Peter and Mathew, 2018). A flash flood occurs naturally and is impossible to stop, nevertheless, it is crucial to raise awareness among stakeholders and explore the available control measures. The government of Bangladesh has been trying to establish several structural and non-structural measures to reduce the probability of flash floods and their damage. Those efforts have not been enough to reduce the risk of flash floods. To lessen the damage induced by flash floods, more studies are warranted on flash flood occurrence and risk management techniques from the farmers perspective. It is important to investigate each flash flood-prone area and the reasons for its intensification. Currently, there is a dearth of literature focused on analyzing how flash floods affect farming systems and agricultural productivity (Khan *et al.,* 2012; Ahmed *et al.,* 2017; Kamruzzaman and Shaw, 2018), as well as assessing the general preparedness of the farmers in terms of alternative livelihoods for coping with flash floods (Haque *et al.,* 2017; Rahman *et al.,* 2018). Thus, it is crucial to investigate the in-depth factors contributing to flash flood intensification and their effects, and to identify solutions for reducing their risk. Given its importance, this study was conducted to ascertain how the Haor farmers generally feel about the causes of flash floods, how flash floods affect farming practices and livelihoods, and how to reduce the risk of flash floods in the Sylhet Haor Basin.

Materials and Methods

Study area

The study was carried out in the Haor districts from November 2021 to April 2022. The sample population consisted of 298 farmers who were chosen at random following the multistage sampling method (Harter *et al.,* 2010; Etikan and Bala, 2017) from high-vulnerable (154 farmers) and moderately-vulnerable (144 farmers) flash flood zones (Fig. 1). Different unions belonging to nine upazilas from Sunamganj (South Sunamganj, Jamalganj, Tahirpur), Sylhet (Gowainghat, Companyganj, Zakiganj, Jaintiapur), and Kishoreganj districts (Itna, Mithamoin) were selected, which are at a high risk for flash floods. Also, different unions from seven upazilas belonging to Brahmanbaria (Nasirnagar, Nabinagar), Kishoreganj (Nikli, Austagram), and Maulvibazar (Maulvibazar Sadar, Kulaura, Barlekha) districts were selected, which are at a moderate risk of flash flooding. To specify each farmer's geographic location on maps, their GPS coordinates were logged (Fig. 1).

Selection of survey locations

Earlier, the high and moderate flash flood vulnerable areas in Sylhet Haor Basin were assessed by using multiple flash flood

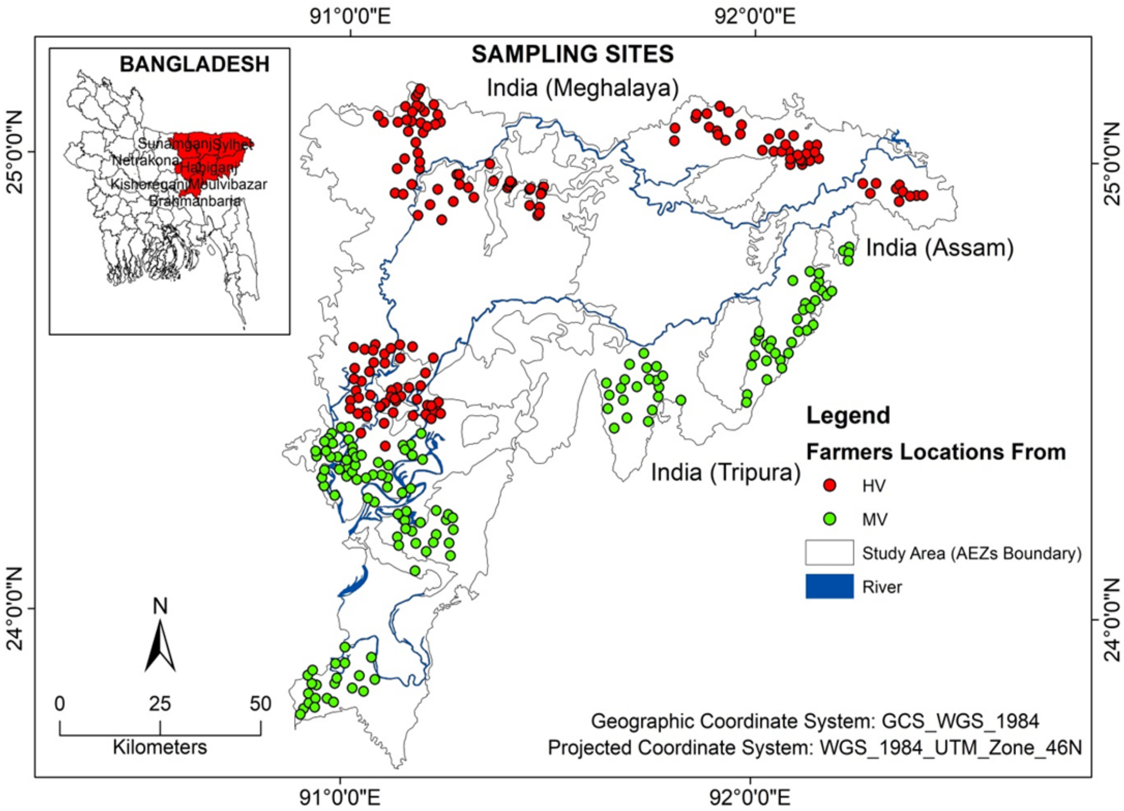

Fig. 1. Map showing the location of selected farmers in the survey area. HV (red circle) and MV (green circle) indicate the location of farmers from high and moderately flash flood vulnerable areas, respectively.

generating indicators and indices following a multi-criteria evaluation technique (Analytic Hierarchy Process, AHP) within the Geographic Information System (GIS). In order to select survey locations in high- and moderate-risk areas, the results of that prior experiment (data not published) were used.

Questionnaire survey

A pre-tested structured questionnaire was developed and used for data collection. Secondary data, including official records, reports, journals, proceedings and other related printed materials were also used as base materials. The questionnaire was pre-tested in the actual field environment before the final data collection and adjusted as necessary. A thorough discussion was held with the experts to finalize the questionnaire. During data collection, the selected respondent farmers' socio-economic characteristics were not taken into consideration. We tried to explore the overall opinion of local Haor farmers irrespective of their socio-economic condition. However, all possible efforts were made to explain the purpose of the study to the farmers in order to get valid and pertinent information on reasons for intensifying flash floods, farming components affected by flash floods, alternative livelihoods after a flash flood, structural measures employed against flash flood damage, and flash flood risk reduction strategies.

Index score and ranking procedure

The index score was calculated by multiplying the frequency count of each of the cells on a scale of the extent of the problem with its corresponding weights. By adding all the values of each cell together, the final index score was found. Finally, the ranking was done based on the index score. The rank order rose in accordance with the higher index score.

Analytical method

The SPSS (Statistical Package for Social Science) software (version 24) was used to calculate frequency and percentage. The collected data were compiled and tabulated using frequency and percentage values.

Results and Discussion

Causes of flash flood severity

The causes of flash flood severity are similar in both high and moderately vulnerable flash flood areas. Improper dredging of rivers and canals followed by ongoing silting of riverbeds are the leading factors contributing to the worsening of flash floods in flash flood-sensitive zones (Fig. 2). Flash flooding is becoming more frequent and severe in Sylhet Haor Basin (Mahtab *et al.,* 2018). The severity of flash floods intensifies due to the reduction or decline in the water-carrying capacity of rivers (Kamal *et al.,* 2018). Most rivers are clogged with material from Bangladesh and upstream areas of India (Shuvo *et al.,* 2021). Due to siltation, the rivers that run over the Sylhet region, particularly Surma and Kushiayara, lost a significant amount of their ability to convey water. Agriculture practices, hill-cutting, and unplanned urbanization all contribute to the siltation of rivers and declining navigability. The capacity of the Surma and Kushiyara rivers to carry water in some sections and to be navigable was both lost with the construction of bridges at their confluence. As a result, the Haor Basin experiences prolonged waterlogging, which is one of the main reasons for the severe flash flood in Sylhet Haor Basin (Sinha *et al.,* 2018). Regular flooding is mostly caused by the construction of erroneous roads and dams. It is believed that the newly built road along the Haor for easy connections in three upazilas (Austagram, Mithamoin, and Itna) may aggravate flash floods. Rainwater from Meghalaya and Assam upstream is regularly transported to the Meghna River. Several experts claimed that the center of the Haor road prevents the water from flowing freely (Nahar *et al.,* 2018). Haor farmers in areas with high flash flood hazards believe that the severity of flash floods is due to poor maintenance of flash flood barriers and channel filling (Fig. 2).

Flash flood impacts on farming systems

We have evaluated the vulnerability of several farming system components to flash floods (Table 1). It reveals that agriculture, livestock, and fisheries sectors are all affected by flash floods. However, the effect was severe in highly vulnerable areas and moderate in moderately-vulnerable areas. Agriculture is the most frequently affected sector compared to the other two sectors. The Haor area has around 0.71 million ha of net cultivable land and annually produces more than 5.25 million tons of paddy. However, an unexpected flash flood could wipe off nearly 0.33 million ha of agricultural production, worth $32.6 million or 3% of the country's GDP contribution from the agricultural sector (Hoq *et al.,* 2021). In both high- and moderately flash flood-prone

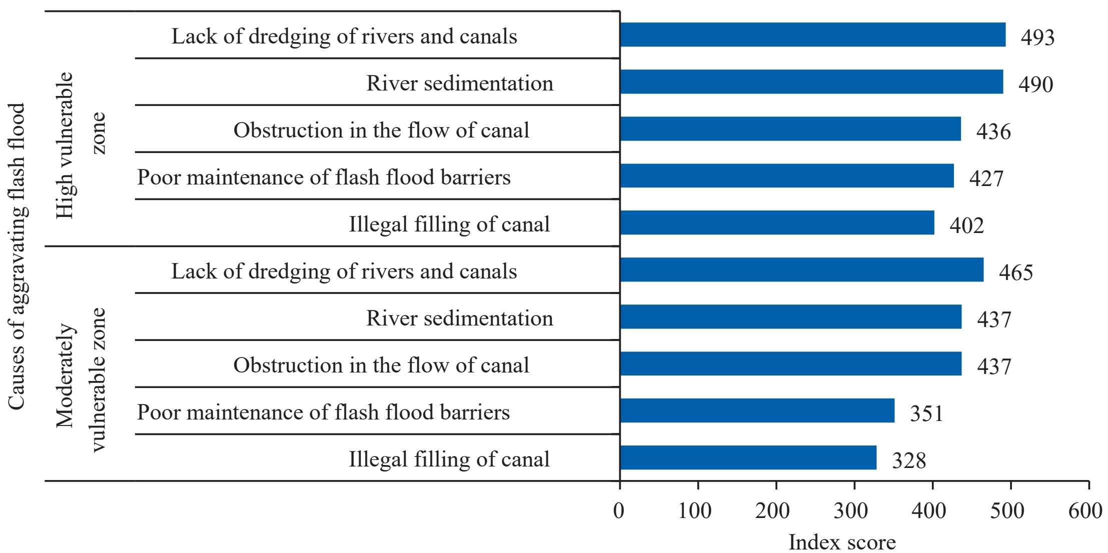

Fig. 2. Causes of flash flood severity in high and moderately flash flood vulnerable zones. On a four-point rating scale, 154 farmers from areas with high and 144 farmers from areas with moderate flash flood vulnerability were asked to rank the aforementioned key five factors (1 = disagree; 2 = neither agree nor disagree; 3 = agree, and 4 = strongly agree) to determine index score for each of the causes. Lastly, the causes were ranked according to their individual index score. The formula was: index score = (number of disagreed farmers × 1) + (number of neither agreed nor disagreed farmers × 2) + (number of agreed farmers × 3) + (number of strongly agreed farmers × 4).

Table 1. Different components of farming system as affected by flash flood in high and moderately flash flood vulnerable zones

Vulnerable zone	Components	Level of impact				Index score
		Not affected (0)	Less affected (1)	Moderately affected (2)	Severely affected (3)	
High (n = 154)	Agriculture (Boro rice production)	-	-	3.2	96.8	457
	Livestock	-	7.1	27.9	64.9	397
	Fishery	-	14.3	39.6	46.1	357
Moderate (n = 144)	Agriculture (Boro rice production)	-	-	95.8	4.2	294
	Livestock	2.8	22.2	70.8	4.2	254
	Fishery	10.4	41.7	47.9	-	198

Total no. of respondents (n = 298). 0, 1, 2, and 3 scales indicate different levels of impact. Values under each 'level of impact' indicate percentage of respondents. Farmers were asked about the level of flash flood impact on different components of farming system. They scored using a four-point rating scale (0 = not affected; 1 = less affected; 2 = moderately affected, and 3 = severely affected). Finally, the index score for each component was calculated by using the following formula: index score = (number of respondents × 0) + (number of respondents × 1) + (number of respondents × 2) + (number of respondents × 3).

areas, farmers claimed livestock was more adversely affected by flash flooding than the fisheries sector (Table 1). An empirical analysis of the literature revealed that food insecurity highly affects the Haor population, whose rural households depend heavily on agriculture and cattle for their livelihood (Shaw, 2006; Rahman *et al.,* 2015). Lack of pasture land, inadequate veterinary care, and a scarcity of feed and fodder because of flash flooding have all made it difficult to raise livestock in the Haor region (Thomas *et al.,* 2013). In the Haor region, increased river siltation brought on by flash floods has resulted in the loss of fish habitats. Moreover, there are not enough protections against the detrimental effects of building roads and flood control embankments on fishing resources (Vatsa and Joseph, 2003).

Flash floods impact on livelihoods

Flash floods have a significant impact on the occupation and income of the farmers. Also, several researchers asserted that flash floods not only compel people to alter their occupations but also have a detrimental impact on people's income (Rahman *et al.,* 2015; Hossain *et al.,* 2017). In high- and moderately susceptible flash flood zones, we asked Haor farmers about their alternate means of surviving after a severe flash flood (Fig. 3). The majority of Haor residents primarily depend on farming, raising cattle, and fishing for their livelihoods; but, during flash floods, they temporarily switch their occupations to retain their livelihoods, despite limited alternative opportunities. On an average, 52% of Haor farmers switch to fishing instead of cropping, and 50% switch to soil digging (Fig. 3). In addition, a substantial proportion of them work as day laborers, collect sandstone, build or operate boats, migrate to urban areas, operating tourist boats or automobiles. Few farmers are involved in the business. During the vulnerable period in flash flood-prone areas, migration of occupations to various types of limited-opportunity employment has also been documented (Raihan and Hossain, 2021; Parvez *et al.*, 2022). Flash floods make people vulnerable by stripping them of their property and agricultural-based livelihoods, leaving them with insufficient resources to recover from the situation (Dayton-Johnson, 2006; Shaw, 2006). Nevertheless, catching fish and day labor are two main post-flash flood occupations that Haor farmers engage in to sustain their existence in moderately flash-prone vulnerable areas (Fig. 3).

Structural measures against flash floods

We queried Haor farmers for their thoughts on the types of physical barriers against flash flood damage in flood-prone areas (Table 2). Irrespective of flash flood-vulnerable areas, most of the farmers opined the highest priority to embankment construction followed by concrete/stone dams, sandbags, and submerged dams and rubber dams to reduce the impact of flash floods on individual properties or entire wetlands (Table 2). Structural flood management methods are used to protect people and property, to reduce risk or influencing the nature or likelihood of an event. Such actions include highly constructed interventions such as dams, dykes, and reservoirs as well as more natural methods like wetland and river restoration (Rahman and Salehin, 2013; Dey *et al.,* 2021). From early times, dams played an important role in protecting people against frequent floods in flood plains and became the most preferred option for flood management. Earth embankments, also known as levees or dykes in some countries, are used to restrict the flow of current within certain areas along a stream or to prevent flooding due to high waves or tides. Floodplain areas exposed to flash floods is limited by retaining flow within the dam, which prevents seasonal floodplain inundation. It disrupts lateral hydrological connectivity

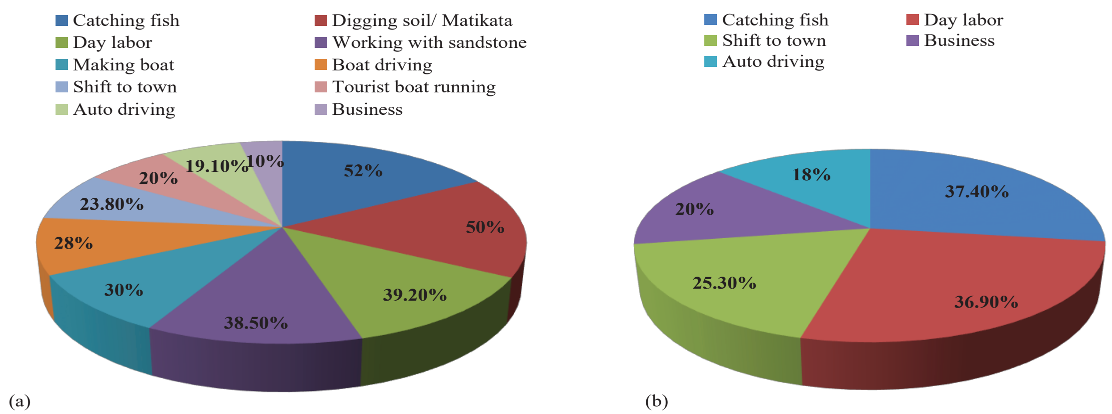

Fig. 3. Post-flash flood alternative livelihoods adopted by Haor farmers in (a) high and (b) moderately flash flood vulnerable zones. Numbers of respondents were 154 and 144 from high and moderately flash flood vulnerable zones, respectively.

Table 2. Distribution of structural measures that act as barrier against flash flood damages in high and moderately flash flood vulnerable zones

Vulnerable zone	Physical barrier	Categories				Index score
		Not a barrier (0)	Somewhat of a barrier (1)	Moderate barrier (2)	Good barrier (3)	
High (n = 154)	Embankments (earthen dam)	-	3.9	38.3	57.8	391
	Concrete or stone dams	3.2	16.9	35.7	44.2	340
	Sandbags	9.1	33.8	3.9	53.2	310
	Submergible embankments	5.8	55.8	35.1	3.2	209
	Rubberdams	10.4	48.1	40.9	0.6	203
Moderate (n = 144)	Embankments (earthen dam)	-	6.3	36.8	56.9	361
	Concrete or stone dams	-	7.6	63.9	28.5	318
	Sandbags	-	40.3	3.5	56.3	311
	Submergible embankments	-	35.4	60.4	4.2	243
	Rubberdams	5.6	49.3	42.4	2.8	205

Total no. of respondents (n = 298). 0, 1, 2, and 3 scales indicate different levels of barrier. Values under each 'level of barrier' indicate percentage of respondents. Farmers were asked to categorize different structural measures that can act as a barrier against flash flood damage. They scored using a four-point rating scale (0 = not a barrier; 1 = somewhat of a barrier; 2 = moderate barrier, and 3 = good barrier). Finally, the index score for each physical barrier was calculated by using the following formula: index score = (number of respondents × 0) + (number of respondents × 1) + (number of respondents × 2) + (number of respondents × 3).

along the river corridor, with diverse impacts on both the channel and its floodplain. On the other hand, dams are constructed across valleys or rivers to store, control and divert water for various purposes such as agricultural production, hydroelectricity generation, human and industrial use, and flood mitigation. Flood control dams store all or portion of the floodwater in reservoirs, especially during peak floods, and then gradually release the water. However, structural measures can only reduce the impact of flash floods. No intervention can stop heavy rain or high tides.

Flash flood risk reduction strategies

Flash floods cannot be prevented, but their risk can be reduced by adopting right strategies. We asked Haor farmers about possible solutions to the risk of flash floods in their area. According to the degree of flash flood risk, Haor farmers prioritize different strategies (Table 3). For flash flood risk management, Haor farmers put the highest priority to increase the height of embankments and dams as well as installing more flood barriers (embankments or dams) in areas with a high and moderate risk of flash floods (Table 3). High-rise embankment or dam along the perimeter of wetlands block flash flood waters for several days, giving people time to harvest their boro crops before the land is completely inundated (Ahmed, 2015). For flood risk management in the Haor Basin, farmers raised high demands for a better early warning system, restoration of rivers to their natural channels and an improved drainage system

Table 3. Prioritizing risk reduction strategies for flash flooding in high and moderately vulnerable zones

Vulnerable zone	Solutions	Priority level					Index score
		Not a priority (0)	Low (1)	Medium (2)	High (3)	Essential (4)	
High (n = 154)	Increasing height of embankment/dam	-	-	-	20.1	79.9	585
	Put up more flood barriers (Embankment/dam)	-	-	1.3	22.7	76.0	577
	Better early warning system	-	-	-	68.2	31.8	511
	Improve drainage system	-	-	12.3	53.2	34.4	496
	Rise of road elevation	-	0.6	3.2	72.7	23.4	491
	Restore rivers to their natural courses	-	0.6	9.7	64.3	25.3	484
	Construct buildings or houses above the flood levels	-	0.6	28.6	65.6	5.2	424
	Reforestation with Hijol, Karach	3.2	11.7	57.8	24.7	2.6	326
Moderate (n = 144)	Increasing height of embankment/dam	-	-	-	25.7	74.3	539
	Put up more flood barriers (Embankment/dam)	-	-	2.8	20.1	77.1	539
	Restore rivers to their natural courses	-	0.7	9.0	52.8	37.5	471
	Improve drainage system	-	-	6.3	67.4	26.4	461
	Better early warning system	-	-	2.1	82.6	15.3	451
	Rise of road elevation	-	-	6.9	76.4	16.7	446
	Construct buildings or houses above the flood levels	-	-	40.3	46.5	13.2	393
	Reforestation with Hijol, Karach	6.3	21.5	64.6	6.3	1.4	252

Total no. of respondents (n = 298). 0, 1, 2, 3, and 4 scales indicate different levels of priority. Values under each 'level of priority' indicate percentage of respondents. Farmers were asked to prioritize different strategies for reducing flash flood risk. They scored using a five-point rating scale (0 = not a priority; 1 = low priority; 2 = medium priority, 3 = high priority, and 4 = essential). Finally, the index score for each risk reduction solution was calculated by using the following formula: index score = (number of respondents × 0) + (number of respondents × 1) + (number of respondents × 2) + (number of respondents × 3) + (number of respondents × 4).

(Table 3). It is evident that the water carrying capacity of the rivers flowing over Sylhet region including Surma and Kushiayara, has been greatly reduced due to siltation. Rivers and channels are losing their capacity to drain water due to sedimentation in the river bed, (Jashim, 2022). When the floodwater cannot drain naturally, it inundates floodplains. It is necessary to adjust the carrying capacity of rivers through capital dredging to facilitate uninterrupted flow of flood water into the Bay of Bengal. Along with the dam, the authorities need to install pumps to pump the water to avoid waterlogging. Consideration should be given to Geographical patterns and river networks should be considered while conducting thorough research before starting any construction process. In an interview with Mongabay, Mirza emphasized the need for infrastructure planning to consider river and rainfall dynamics to reduce flood risk and have an early warning system to minimize damage (Siddique, 2022). For Bangladesh to develop accurate forecasts and an evacuation system, this can happen with the help of upstream India, which can provide real-time and advanced warning data. Environmentalists and water and river experts have suggested that flood forecasting systems need to be improved by considering hydrologic data from upstream countries.

Conclusion

Flash floods have the greatest impact on livelihoods dependent on agriculture. Recurring flash floods will continue to cause loss and damage and the geographical location of the Haor Basin will not allow overnight large-scale conversion from agricultural livelihood to other secure livelihood options. To ensure continued economic growth in the Sylhet Haor Basin, it is therefore imperative to protect current livelihoods and promote new skill-based options. Improving fishery productivity should be a top priority as the area has huge potential to produce a wide variety of fish, especially in open water. However, with the implementation of structural and non-structural measures to reduce the risk of flash floods affecting agriculture and other livelihoods as a whole, government, development partners, and non-government organizations should focus on vulnerable Haor farmers whose livelihoods are most at risk from flash floods. In the face of acute flash floods, the Haor farmers can be given a decent income guarantee, a better way of living and food security by taking the necessary countermeasures against the flash floods to reduce their livelihood vulnerability to flash floods, promoting economic growth by creating new opportunities, and fostering sustainable development in the Haor Basin.

Acknowledgements

This survey work was financially supported by Krishi Gobeshona Foundation (KGF), Dhaka, Bangladesh under the Project "Modeling Climate Change Impact on Bangladesh Agriculture (MCCA), CRP II, Phase 2". This research work was also supported by the Ministry of Science and Technology under NST fellowship program, Government of Bangladesh.

References

Adnan, M. S. G., A. Dewan, K. E. Zannat and A. Y. M. Abdullah. 2019. The use of watershed geomorphic data in flash flood susceptibility zoning: a case study of the Karnaphuli and Sangu river basins of Bangladesh. *Nat. Hazards.* 99(1): 425-448.

Ahmed, F. H. 2015. In: *Protecting crops in Haor areas*. Available via https://www.observerbd.com/2015/03/14/77675.php. Accessed on 14 March 2022.

Ahmed, M. R., K. R. Rahaman, A. Kok and Q. K. Hassan. 2017. Remote sensing-based quantification of the impact of flash flooding on the rice production: A case study over Northeastern Bangladesh. *Sensors*. 17(10): 2347.

Baten, A., P. A. Gonzalez and R. C. Delgado. 2018. Natural disasters and management systems of Bangladesh from 1972 to 2017: Special focus on flood. *OmniSci. A Multidis. J.* 8(3): 35-47.

CEGIS. 2012. Master plan of Haor Area. Ministry of Water Resources, Government of the People's Republics of Bangladesh, Summary Report, Vol. 1, Pp. 1-72.

Dayton-Johnson, J. 2006. Natural disaster and vulnerability. OECD Development Center Policy Brief No. 29; OECD Development Center: Berlin, Germany.

Dey, N. C., M. Parvez and M. R. Islam. 2021. A study on the impact of the 2017 early monsoon flash flood: potential measures to safeguard livelihoods from extreme climate events in the Haor area of Bangladesh. *Int. J. Dis. Ris. Reduct.* 59: 102247.

Etikan, I. and K. Bala. 2017. Sampling and sampling methods. *Biom. Biostat. Int. J.* 5(6): 00149.

Haque, M. M., S. Bremer, S. B. Aziz and J. P. van der Sluijs. 2017. A critical assessment of knowledge quality for climate adaptation in Sylhet Division, Bangladesh. *Clim. Risk Manag.* 16: 43-58.

Harter, R., S. Eckman, N. English and C. O'Muircheartaigh. 2010. Applied sampling for large-scale multi-stage area probability designs. *Handb. Surv. Res.* 2: 169-199.

Hoq, M. S., S. K. Raha and M. I. Hossain. 2021. Livelihood vulnerability to flood hazard: Understanding from the flood-prone Haor Ecosystem of Bangladesh. *Environ. Manage.* 67(3): 532-552.

Hossain, M. S., A. A. Nayeem, A. A. and A. K. Majumder. 2017. Impact of flash flood on agriculture land in Tanguar Haor Basin. *Int. J. Res. Environ. Sci.* 3(4): 42-45.

Islam, M., S. Sallu, K. Hubacek and J. Paavola. 2014. Vulnerability of fishery-based livelihoods to the impacts of climate variability and change: insights from coastal Bangladesh. *Region. Environ. Chang.* 14(1): 281-294.

Islam, Z. and D. Chowdhury. 2022. In: *Flood damages: Farmers face hunger after loss of crops.* Available via https://www.thedailystar.net/environment/climate-crisis/natural-disaster/news/flood-damages-once-healthy-homesteads-now-fighting-hunger-3057086. Accessed on 27 Jun 2022.

Jashim, E. H. 2022. In: *Behind Sylhet region's devastating floods.* Available via https://bangladeshpost.net/posts/behind-sylhet-region-s-devastating-floods-88479. Accessed on 20 Jun 2022.

Kamal, A. M., M. Shamsudduha, B. Ahmed, S. K. Hassan, M. S. Islam, I. Kelman and M. Fordham. 2018. Resilience to flash floods in wetland communities of northeastern Bangladesh. *Int. J. Disaster Risk Reduct.* 31: 478-488.

Kamruzzaman, M. and R. Shaw. 2018. Flood and sustainable agriculture in the Haor Basin of Bangladesh: A review paper. *Univers. J. Agric. Res.* 6(1): 40-49.

Khan, M. N. H., M. Y. Mia and M. R. Hossain. 2012. Impacts of flood on crop production in Haor areas of two Upazillas in Kishoregonj. *J. Environ. Sci. Nat. Res.* 5(1): 193-198.

Khosravi, K., B. T. Pham, K. Chapi, A. Shirzadi, H. Shahabi, I. Revhaug, I. Prakash and D. T. Bui. 2018. A comparative assessment of decision trees algorithms for flash flood susceptibility modeling at Haraz watershed, northern Iran. *Sci. Total Environ.* 627: 744-755.

Mahtab, M. H., M. Ohara and M. Rasmy. 2018. The impact of rainfall variations on flash flooding in Haor areas In Bangladesh. *Water Conserv. Manag.* 2(2): 6-10.

Nahar, N., N. Sultana and J. Miah. 2018. Seasonal land cover changes and its effects on essential services of Haor and non-Haor areas of Kishoreganj district, Bangladesh. *Asia Pac. J. Reg. Sci.* 2(2): 399-429.

Nowreen, S., S. B. Murshed, A. S. Islam, B. Bhaskaran and M. A. Hasan. 2015. Changes of rainfall extremes around the Haor Basin areas of Bangladesh using multi-member ensemble RCM. *Theor. Appl. Climatol.* 119(1-2): 363-377.

Parvez, M., M. R. Islam and N. C. Dey. 2022. Household food insecurity after the early monsoon flash flood of 2017 among wetland (Haor) communities of northeastern Bangladesh: a cross-sectional study. *Food Energy Secur.* 11(1): e326.

Peter, A. and A. Mathew. 2018. Structural flood defence measures and effects on the surroundings. *EPH Int. J. Appl. Sci.* 4: 1-14.

Rahaman, M. S., M. A. R. Sarkar, M. C. Rahman, D. E.B. Limon, M. M. Rashid, M. S. Reza and M.A.B. Siddique. 2022. Profitability analysis of paddy production in different seasons in Bangladesh: Insights from the Haor. *Int. J. Agric. Environ. Food Sci.* 6(3): 327-339.

Rahman, H. M., G. M. Hickey and S. K. Sarker. 2015. Examining the role of social capital in community collective action for sustainable wetland fisheries in Bangladesh. *Wetlands.* 35(3): 487-499.

Rahman, H. T., M. E. Mia, J. D. Ford, B. E. Robinson and G. M. Hickey. 2018. Livelihood exposure to climatic stresses in the north-eastern floodplains of Bangladesh. *Land Use Policy.* 79: 199-214.

Rahman, R. and M. Salehin 2013. Flood risks and reduction approaches in Bangladesh. In *Disaster risk reduction approaches in Bangladesh*. Springer, Tokyo, Pp. 65-90.

Raihan, F. and M. M. Hossain. 2021. Livelihood vulnerability assessments and adaptation strategies to climate change: a case study in Tanguar Haor, Sylhet. *J. Water Clim. Chang.* 12(7): 3448-3463.

Recanatesi, F., A. Petroselli, M. N. Ripa and A. Leone. 2017. Assessment of stormwater runoff management practices and BMPs under soil sealing: A study case in a peri-urban watershed of the metropolitan area of Rome (Italy). *J. Environ. Manag.* 201: 6-18.

Shaw, R. 2006. Critical issues of community based flood mitigation: examples from Bangladesh and Vietnam. *Sci. Cult.* 72(1/2): 62.

Shuvo, S. D., T. Rashid, S. K. Panda, S. Das and D. A. Quadir. 2021. Forecasting of pre-monsoon flash flood events in the northeastern Bangladesh using coupled hydrometeorological NWP modelling system. *Meteorol. Atmos. Phys.* 133(6): 1603-1625.

Siddique, A. 2022. In: *More research about relationship between flash floods and climate change needed.* Available via https://www.preventionweb.net/news/more-research-about-relationship-between-flash-floods-and-climate-change-needed. Accessed on 7 July 2022.

Sinha, V., R. Glémet and G. Mustafa. 2018. Benefit sharing opportunities in the Meghna Basin. Profile and preliminary scoping study, Bangladesh and India.

Bangkok, Thailand: International Union for Conservation of Nature.

Talukder, G. R., M. A. Gazi, K. M. Pradip, E. H. Kazi and N. Sulochana. 2011. Different economic and policy perspectives in micro population for sustainable development: A study of the Haor livelihood in Bangladesh. *Afr. J. Bus. Manag.* 5(6): 2475-2492.

Thomas, T. S., K. Mainuddin, C. Chiang, A. Rahman, A. Haque, N. Islam, S. Quasem and Y. Sun. 2013. Agriculture and adaptation in Bangladesh: Current and projected impacts of climate change. *Intl. Food Policy Res. Inst.* 1281.

Uddin, M. T., N. Hossain and A. R. Dhar. 2019. Business prospects and challenges in Haor areas of Bangladesh. *J. Bangladesh Agric. Univ.* 17(1): 65-72.

Vatsa, K. S. and J. Joseph. 2003. Disaster management plan for the state of Maharashtra, India: evolutionary process. *Nat. Hazards Rev.* 4(4): 206-212.