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Rain and flood characteristics, agricultural damages and coping strategies in North-eastern *Haor* region of Bangladesh

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ABSTRACT

Heavy rain often causes flash flood in the *haor* areas at northeastern region of Bangladesh that brings people's livelihood vulnerable due to destroying the staple food i.e. *Boro* paddy. Although the matter is highly important but it didn't receive proper attention at all. Therefore, the study was conducted to investigate the rainfall characteristics in the riparian and upstream zone and associated disaster due to flood shock in *haor* areas. Both secondary and primary sources of data were collected. Secondary information were collected from published and unpublished literatures, books, newspapers, various offices and webs. Primary data were collcted through consulting stakeholders in the various line ministries, and focus group discussion meeting and questionnaire survey with *haor* farmers. Run-off water fom the rains occurred in the elevated upstream zone like Meghalya, Aasam and Tripura of India, and rains in the *haor* areas are combinely responsible to create flood in *haor* basin at northeastern Bangaldesh. The earthen dams and embankments for protecting flood in the rice growing *haors* are not strong or high enough against the water pressure that eventually collapses and causes flash flood. The soil mass is also hardly available in the *haor* areas to build the embankments boldly or repair them quickly in time. Neverthless, these structural measures for protecting flood and crop loss are not sufficient until the draining capacity of the river networks is fully resumed through proper river administration. Although the *haor* areas experience two major types of flood like early flash flood and monsoon flood. However, the flash flood if occurs early from middle of March to middle of April when the main crop of *haor* areas i.e. *Boro* crop remains at premature stage creates havoc or disaster with food insecurity because it losses paddy grain, fodder, fish, cattle, ducks, poutry, and so on and thus labour hours of the areas. The adaptation and coping strategies against flood shocks to support people's livelihood are also limited in the *haor* areas. Suitable nonstructural measures like rain and flood warning systems can be devised for early forecasting of flooding to ensure save harvest of standing paddy in the areas. Cultivation of *Boro* paddy can also be advanced in innovative way to esacpe the early flash flood effectively. Loan or credit distribution to the affected farmers with zero interest system and agricultural input and extension supports from government might be helpful to shortly start the farm activities soon after flood hit in the *haor* areas.

Keywords: Barak River, *Boro* paddy, Cherrapunji, early warning, flash flood, forecasting, *haor* areas, Kushiyara, rainfall, Surma

1. INTRODUCTION

A number of geo-morphological features like hillocks (*tilas*) and hills, *beels* and *haors* (wetlands) and floodplains make the north-eastern region quite different from the rest of the areas of Bangladesh (Choudhury et al., 2012). The region is located at the foothill of Meghalaya, Assam and Tripura of India (Map 1), and belongs to the Meghna River basin which besides eastern side of the Brahmaputra River basin of Bangladesh (Asaduzzaman and Wang, 2020). *Haors* are of depositional origin and commonly recognized as large bowl- or saucer-shaped tectonic downturns or fresh water floodplains, covering an area 43 percent of the entire northeastern region of the country (Master Plan of Haor Area, 2012a). In more than half of the year (from May to October), *haor* remains submerged under water. Thus, *haor* economy is the economy of deep fresh water and entirely dependent on agriculture. Two percent of national GDP comes from the economic activities of *haor*, estimated at BDT 37,740 million over the last decade (Barkat et al., 2019). Some tea gardens and tea manufacturing industries quite far from *haor* areas are existed in the hilly areas of Sylhet, Moulvibazar and Habiganj districts.

Map 1 Major part of *haor* areas at northeast Bangladesh. Source: Google Earth; accessed on 23 October 2022.

Image 1 Growing *Boro* paddy (vegetative stage) in a *haor* area.

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Historically, *haor* areas are the most benighted regions of Bangladesh. *Haor* people face serious deprivation of public and private support services. No agro-based industry has been so far developed in *haor* areas. Thus, the *hoar* dwellers live in systematized poverty and marginality (Barkat et al., 2019). Nevertheless *haors* have profound ecological, socio-cultural, economic and commercial importance and values in Bangladesh. The *haors* are enriched with various aquatic flora and fauna including 140 species of fish (Rahman, 2010; IUCN, 2015). More than 100,000 migratory birds visit the area annually especially during winter (Mahmud, 2019). Tanguar *Haor* in Sunamganj, a large freshwater wetland, is included in the Ramsar site (IUCN, 2015). During dry season, *haors* are used for agriculture especially for *Boro* paddy cultivation (Image 1) and during rainy season it is used as fresh water fisheries. Besides paddy cultivation and fishing, some business activities in small scale are also observed in the *haor* areas centering aquatic resources, duck, vegetables, non-rice crops, fruit trees, livestock and poultry. Swamp forests which composed of water (-logging) resistant trees like hizal (*Barringtonia acutangula*), tamal (*Diospyros cordifolia*), barun (*Crataeva nurvala*), karoch (*Pongamia pinnata*), panibaj (*Salix tetrasperma*), baladumur (*Ficus heterophylla*) etc are existed in the *haor* areas.

A flash flood is a sudden rush of plenty of water flowing down to a narrow channel and/or over a sloping surface caused by heavy or intense rainfall especially in upstream hilly areas within a short period of time with no or a little chance of advance warning or forecasting the extreme weather (Sweeney, 1992). Flash flood hits the *haor* region and collapses the flood protection infrastructures like earthen dams and embankments with inundating and destroying the growing paddy during the months of April and May, which is the most common climate shock, occurs in the *haor* region. Dependency on a single crop (i.e. *Boro* paddy) and if this is spoiled early by hitting a flash flood makes the *haor* residence vulnerable mainly due to food insecurity. Additionally, a long monsoon flood that occurs during the months from May to September or even up to October every year affects the life and livelihood of the people in the *haor* areas.

The sudden and intense rainfall before the onset of monsoon season causes the early flash flood in the *haor* areas. The amount of rainfall in *haor* region is naturally heavier than the other parts of the country and almost double than the national average (around 200 cm/year) (Bari et al., 2015). Not surprisingly, the total rain occurs in Sylhet area during the months of March and April (i.e. in the time of early flash flooding) is about 3-fold than the amount of rain of country's mean in the same time (Bari et al.). Geo-morphologically, the region is sitting in between the Meghalaya of India in the north, and Assam and Tripura at the east. The topography of *haor* region is much lower to that at adjacent Indian region. Thus the *haor* belt not only receives its own rainwater but also take the run-off water from the said upstream Indian catchments. Cherrapunji, a place of Indian Meghalaya is one of the highest rainfall regions of the world which is sitting just above the *haor* region of Bangladesh (only 30 km bird fly distance from the nearest Bangladesh border). So, the temporal and spatial variability along with total rainfall occurs in the northeastern part of Bangladesh and its upstream Indian areas are highly important to analyze the flood characteristics in the *haor* areas but the matter didn't receive proper attention at all (Zafor et al., 2016; Islam et al., 2019).

Flash flood and associated disaster are not new in the *haor* areas. But the ever first and extensive flash flood followed by havoc with food insecurity (Roy et al., 2017) in *haor* areas occurred in March-April of 2017 that brought the matter to a new dimension. Therefore, the aim of the study is to report the rain and flood characteristics, its effect on the destroying the earthen infrastructures and crops in the region, and associated vulnerability and coping strategy of the people therein.

2. METHODOLOGY

The study was conducted in the Laboratory of Plant Ecology, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh during the time from 2018 to 2021. The data collection strategy was mix mode. Both the secondary and primary sources of data were collected. Secondary information from published and unpublished literatures, books, journals, newspaper, web etc., was collected. Stakeholders working in the Department of Agricultural Extension (DAE), Bangladesh Water Development Board (BWDB) etc were interviewed physically and over telephone. Focus Group Discussion (FGD) meeting with *haor* farmers was conducted to gather the collective response of *haor* problems (Image 2). An open ended or semi-structured questionnaire was prepared to collect the primary data on crop production and livelihood related issues from the *haor* farmers. Before the main survey, the questionnaire was pretested with some farmers for necessary adjustments or corrections. A total of 2054 farmers from various places of *haor* areas during the study period were personally interviewed with well trained enumerators using the pretested questionnaire. The information in filled questionnaire were re-sequenced, coded, recoded or other conversion were performed as per needed, and the data were inputted to software programmes by the well trained data entry operators. Descriptive statistics were used to visualize the primary data from *haor* farmers.

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Image 2 Focus Group Discussion (FGD) meeting with some *haor* farmers.

3. RESULTS AND DISCUSSION

Distribution and topography of the *haors*

Haors are large saucer or bowl-shaped surface depressions also known as a back swamp located in the seven north-eastern districts of Bangladesh such as Sunamganj, Sylhet, Habiganj, Maulvibazar, Netrakona, Kishoreganj and Brahmanbaria. The districts cover an area of 1.99 million hectares (mha) (Map 2). It is a patch of wetland habitats including rivers, channels and canals, streams, large areas of periodically immerses cultivated lowland and *beels*. During monsoon, *haors* receive surface runoff water from rivers and canals to become vast extents of unstable water. There are 373 *haors* comprised about 0.859 mha which is around 43 percent of the total area of those seven districts (Table 1).

The *haor* region receives water from the catchment slopes of the Shillong Plateau across the borders in India to the north and the Tripura Hills of India to the south-east. This wet land area is criss-crossed by a number of trans-boundary rivers coming down from the hills of India with huge amount of runoff water (Rabby et al., 2011; Ahmed, 2012). The topography of *haor* regions is uneven and the *haors* are below 8 meters from the surrounding normal land thus flooded for 7-8 months to a depth of 5 meters or more during the monsoon season (NERP, 1995). The *haor* region is the upper part of the Meghna River basin. The Surma-Kushiyara floodplain is the major catchment of the *haor* areas whose elevation ranges maximum up to 10 m above mean sea level (masl). For example *Tanguar Haor* that is located in two upazilas of Sunamganj district namely Dharmapasha and Tahirpur whose altitude is only 2.5-5.5 masl.

River course draining the *haor* areas

The Barak and Surma-Kushiyara system

The main source of Surma (900 km in length) is the Barak River, which originates in the Manipur Hills of India. Afterward it flows through Mizoram and Assam. The Barak flows west and on reaching the border at Amalshid in Sylhet district, it bifurcates to form the steep and highly flashy rivers the Surma (northwest arm) and the Kushiyara (southwestern arm) (Map 3). The Surma River is fed by tributaries from the Meghalaya hills. The system drains one of the world's heaviest rainfall areas (e.g. about 11,500 mm/year at Cherapunji, Meghalaya, India; 1973-2021 average) and passes through many *haors* of northeastern areas of Bangladesh.

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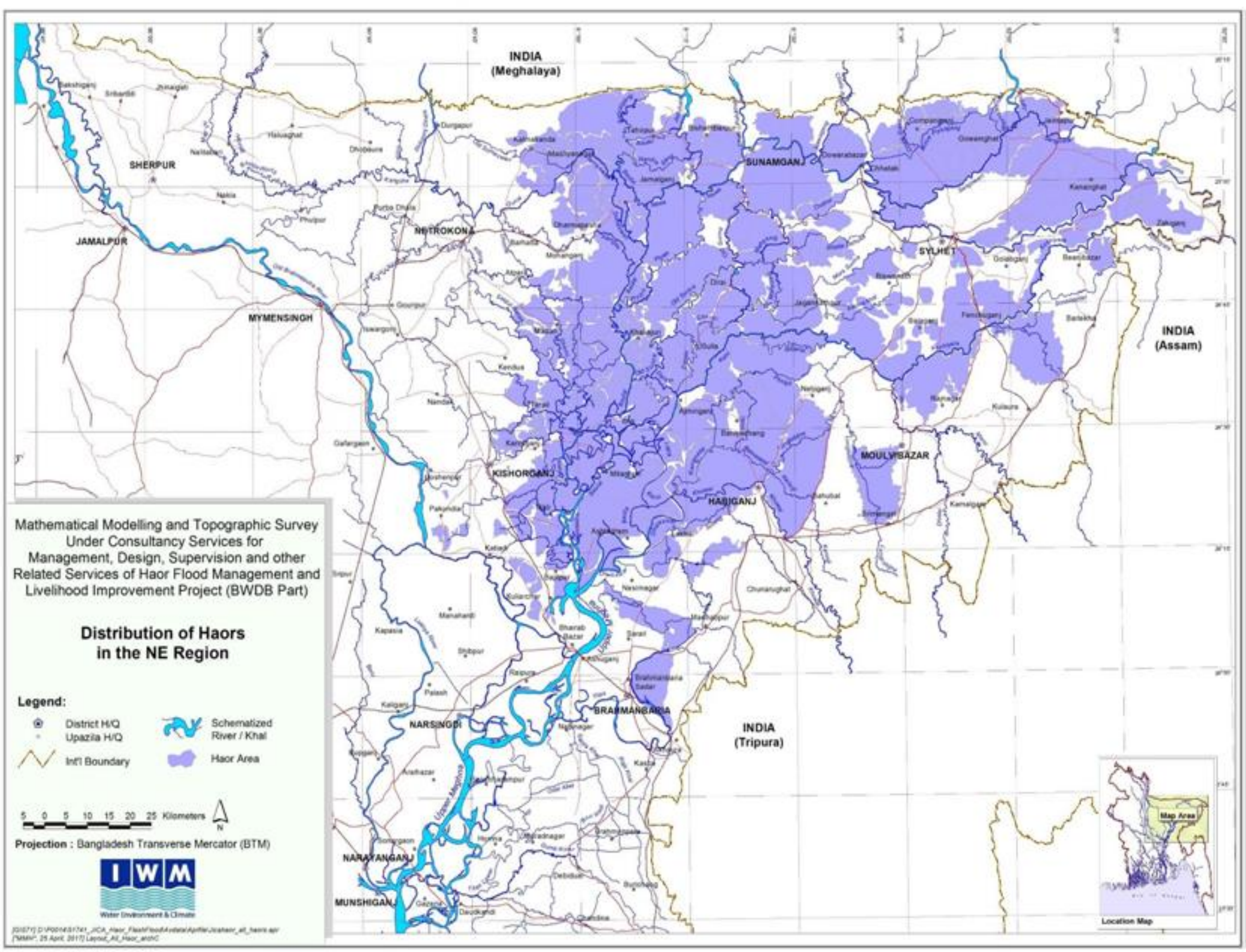

Distribution of *haors* at north-eastern region of Bangladesh

Map 2 North-eastern *haor* region of Bangladesh and distribution of *haors*. Bottom part is adapted from Institute of Water Modelling (IWM), BWDB.

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Table 1 Distribution and area of northwestern districts and *haors* of Bangladesh

Hoar district	Total area (ha)	Area of *haors* (ha)	Number of *haors*	Name of major *haors*
Sunamganj	367,000	268,531	95	Tanguar, Shanir, Dekhar, Kalikota, Naluar, Pagner
Sylhet	349,000	189,909	105	BoroHaor, Patharchuli, Dhamrir, Banaiya
Habiganj	263,700	109,514	14	Gungiajuri, Ikram-Sangar, Makalkandi
Moulvibazar	279,900	47,602	3	Hail, Hakaluki, Kawadighi
Netrokona	274,400	79,345	52	DingiPota, MedarBeel, Talar
Keshoreganj	273,100	133,943	97	BoroHaor, Khunkumi, Mithamain
Brahmanbaria	192,700	29,616	7	Dattakhola, Tikkar Par
Total	1,999,800	858,460	373	

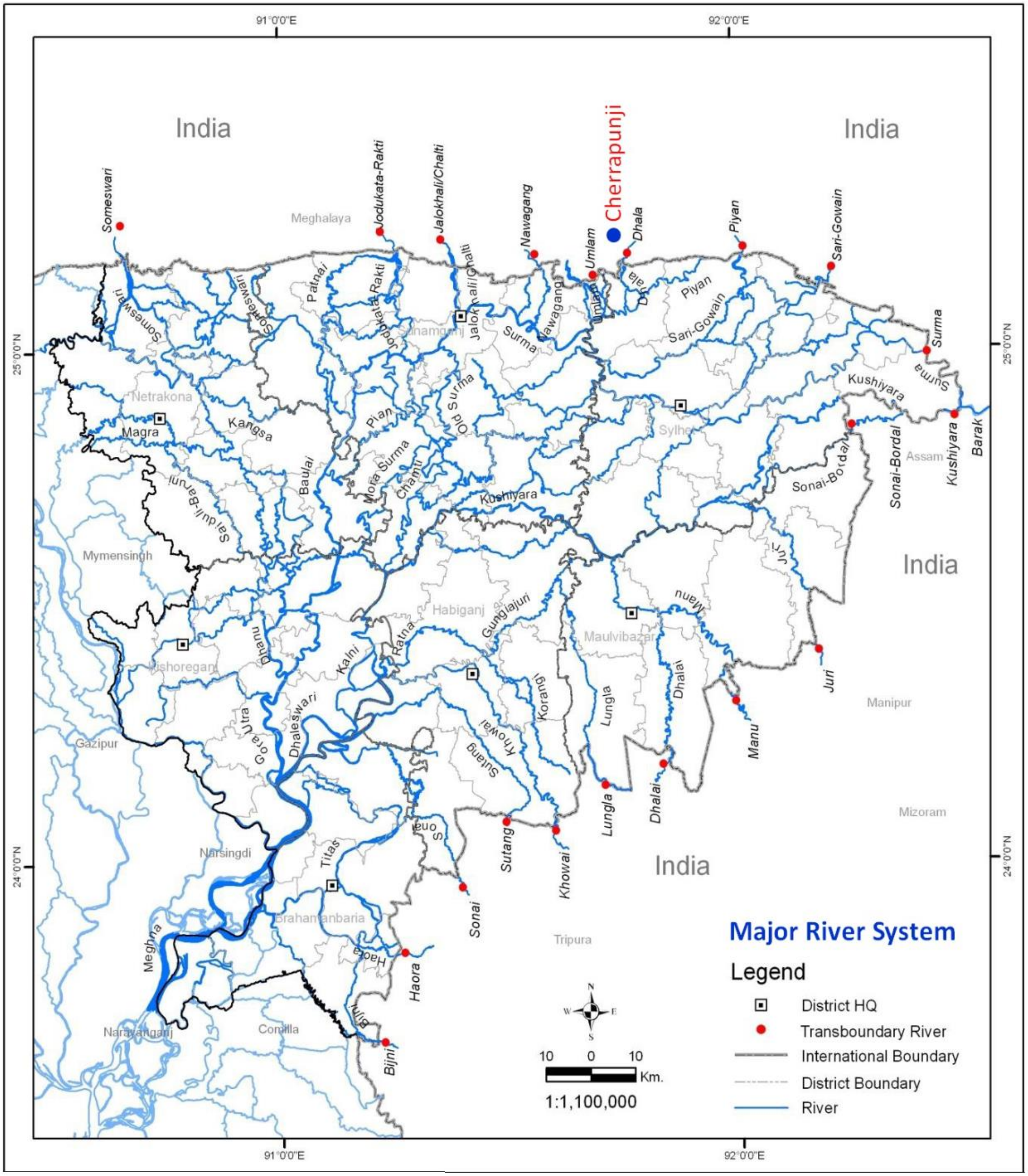
Source Master Plan of Haor Area (2012a).

Map 3 The Barak, Surma and Kushiyara Rivers at Amalshid, Sylhet district at Bangaldesh-India border. Source: Google Earth; accessed on 23 October 2022.

The *haor* region as well as Meghna basin is drained ultimately into the Bay of Bengal through the Surma-Baulai, Kangsa-Dhanu and Kushiyara-Kalni River systems.

Surma-Baulai River system

Flowing north of the Sylhet basin, the Surma receives tributaries from Khasi and Jaintia hills. East to west they are Lubha, Hari, Goyain Gang, Piyain, Bogapani, Jadukata, Shomeshwari, Kangsa and Mogra. The Surma bifurcates south of Mohanganj soon after it receives Kangsa and further south the Mogra (Map 4). The western channel is known as Boulai in its upper course, Dhanu in the middle and Ghorautra lower down.



Map 4 River neworks in the north-eastern areas of Bangladesh (adapted from Master Plan of Haor Area, 2012b).

Kangsa-Dhanu River system

Some trans-boundary rivers like Someswari, Malijhi, Chillakhali, Bhogai and Nitai Rivers coming down from India along the periphery of the *haor* areas (Map 4). The Kangsha and Dhanu Rivers are the major and the Saiduni-Baruni and Gorautra Rivers are the contributing rivers of this system. Flowing down the system drains at the Meghna River at the borders of Bajitpur and Bhairab upazilas of Keshoreganj district (Map 5).

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Map 5 Rejoining of Surma (as Ghorautra) and Kushiyara (as Kalni) Rivers as flowing to Meghna River at Bhirab, Keshoreganj district. Source: Google Earth; accessed on 23 October 2022.

Kushiyara-Kalni River system

Kushiyara River is a distributary river in Bangladesh and Assam, India. Initially, the Kushiya River runs as the border between Bangaldesh and India. It receives tributaries from the Sylhet Hills and Tripura Hills to the south, the principal one from the Tripura Hills being the Manu. Altogether, the Kushiyara River runs about 160 km and crosses over Zakiganj, Golabganj, Fenchuganj, Balaganj, Rajnagar, Maulvibazar, and Nabiganj. Flowing forward, the Kushiyara is named as the Kalni River and it is joined to a major offshoot (distributary) from the Surma locally known as the Ghorautra River (Map 4). When the Surma (as Ghorautra) and the Kushiyara (as Kalni) finally rejoin in Kishoreganj district above Bhairab Bazar, the river is known as the Meghna River which eventually flows into the Bay of Bengal (Map 5).

In and around the Surma and Kushiyara Rivers, there lies a complex basin area comprised of depressions i.e. *haors*. Most of the Surma system incorporates the *haor* basin, where the line of discharge is not clear or well defined at all. During the dull season the Kushiyara River exhibits to dry up almost out-and-out in a few places with the mass of the charge being shifted subsurface, such as in the intertwine stream area at south of Ajmiriganj Bazar. About sixty percent catchment area of the Surma and Kushiyara Rivers draining the *haor* region.

The *haor* region is appraised to be descending from 4 mm to 2.1 cm every year as a result of the down-pushing for Shillong plateau. This go down means that annual flooding will become more extensive and will eventually be exacerbated by the sea-level rise (IFAD, 2011).

Rainfall occurs in the *haors* areas and upstream catchments

Avergae normal rainfall (as annual rainfall that average of 30 or 35 consecutive years) of Sylhet and Sreemangal (Moulvibazar district) Meteorological (Met) Stations along with country average normal rainfall are shown in Figure 1. Most rainfall occurs from April to September with the peak thrust during the months of June and July. The amount of rainfall is too small and negligeable from November to February. The amount of monthly total rainfall in Sylhet Met Station during the time of early flash flood (from March to May) and monsson flood (from June to September) is distinctly greater than the national average and also higher than that occurred in the Met Station nearby southern district i.e. Moulvibazar. The result is very much similar to that of Bari et al., (2015). The amount of country average rainfall is smaller than that occurred in Sreemangal Met Station from the month of February to May but higher during the remaining months of the year.

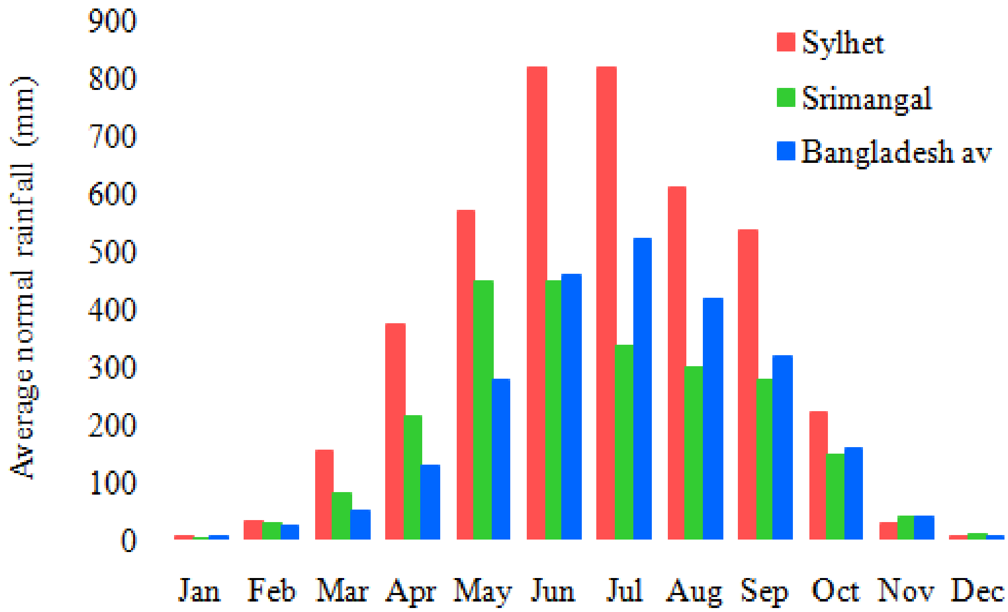

Figure 1 Average normal monthly rainfall in Sylhet region and country mean. Source: Bangaldesh Meteorological Department (BMD).

Choudhury et al., (2012) described seasonal variations of rainfall while Roy (2013) analysed time series, factors involved and impacts analysis of rainfall in northeastern part of Bangladesh. From a linear regression analysis of rainfall data of Sylhet region from 1981 to 2015 years, Islam et al. (2019) found that the yearly rainfall pattern was found erratic with more likely to vary in between 16 and 18 percent from year to year. From the time series trend analysis, they found that the annual and seasonal rainfall in Sylhet Met Station has been decreased about 29 mm/year with a 4 mm downturn per year in recent times due to change in climatic pattern. However, Islam et al. pointed out that high intensity of rainfall within a short peeriod of time increases the flood risk in northeastern part of Bangladesh.

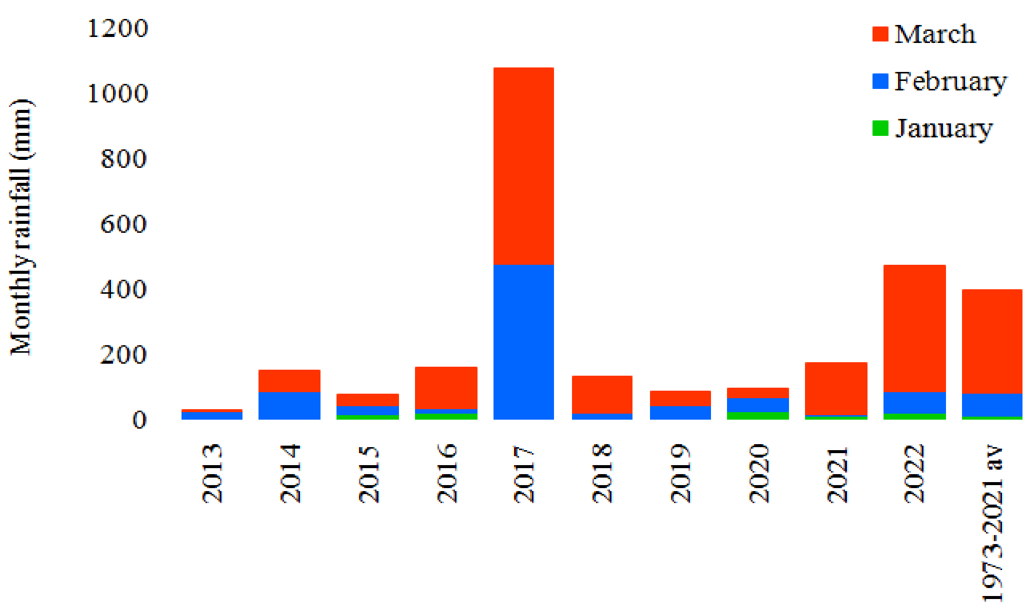

Figure 2 Rainfall during January, February and March months at Cherrapunji, Meghalaya, India.
Source https://cherrapunjee.com/100-years-rainfall-data/; accessed on 18 October 2022.

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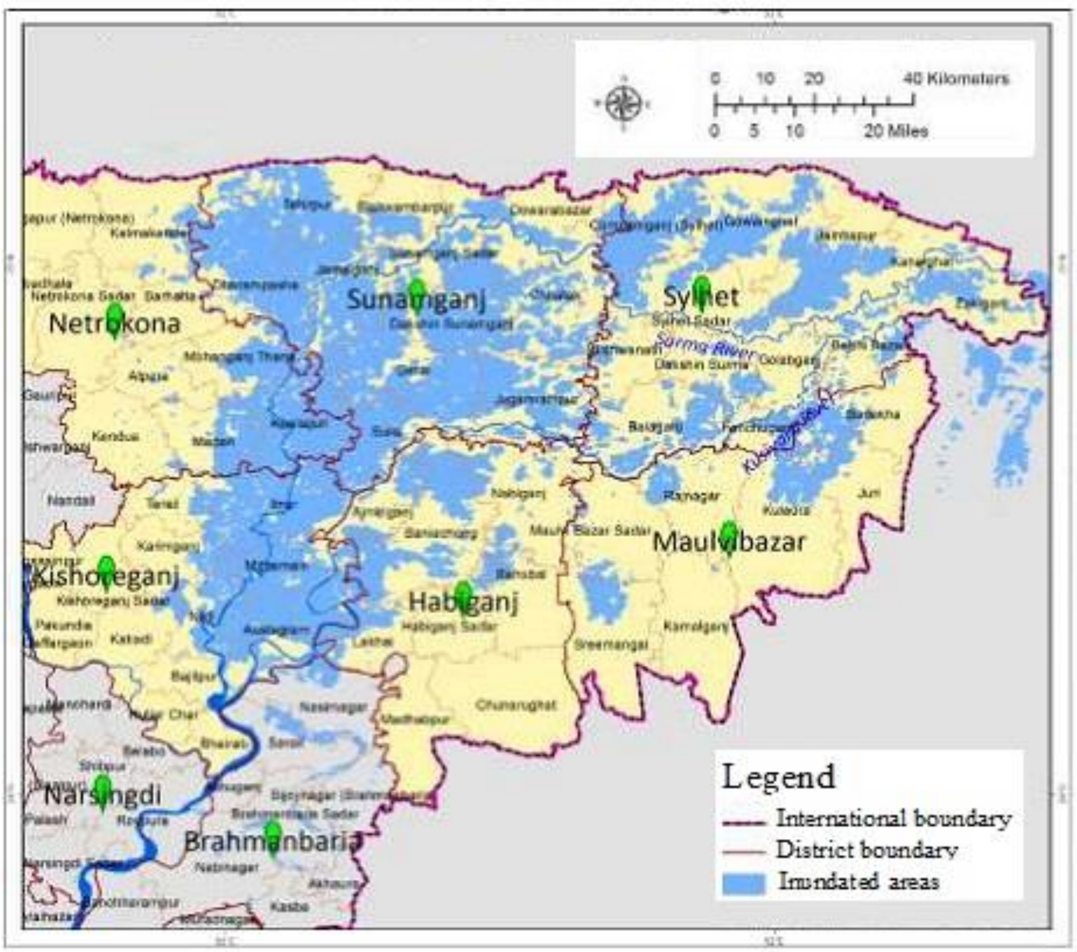
The changes in the rainfall, most likely induced by climate change, in Cherrapunji, known for the world's heaviest rainfall, is highly important in context of the early flash flood in the *haor* areas of Bangladesh. The elevation of Cherrapunji and Shillong of India from sea level is too high as 1430 m and 1525 m, respectively. Whereas the elevation of *haor* areas of Bangladesh is only 2.5-5 m in most places and maximum upto 10 m in few places. There is a strong ground to guess that a change in the rainfall in Cherrapunji may have shortened the recurrence of 5 to 6 years gap of flash floods in the *haor* areas (Ray, 2022). In addition of local rain occurred in north-east Bangladesh for example, the heaviest rainfall during February and March in 2017 in Cherrapunji of Meghalaya, India that recorded 5.5 times more rainfall that it did during the same period a year earlier or later (Figure 2) was the prime reason for creating early flash flood in *haor* areas of Bangladesh. The rainfall during February 2017 in Cherrapunji run-off over the local catchment in *haor* areas and saturated these while the rain occurred during the month of March created the worst ever flash floods in the Netrokona, Sunamganj, Sylhet, Moulvi Bazar, Habiganj and Kishoreganj districts. Not only did it bring about disaster or havoc with loss of standing or growing *Boro* paddy but also caused extensive damage to fodder, ducks, poultry, fisheries and livestock in the area.

The average rainfall during the month of March and April in Cherrapunji over 1973-2021 period was also much higher as 317 and 855 cm, respectively (Figure 2) indicates that *haor* areas remain constantly under the threat of flash flood every year even there is no rain is occuured in *haor* areas of Bangladesh.



Map 6 Inundated areas due to flash flooding over the *haor* region as of 12 May 2017 (adapted from HCTT CAN, 2017).

Flood characteristics and land inundation in *haor* areas

The *haor* flood is strongly associated with the rainfall in the upstream Indian catchments such as Meghalaya, Barak and Tripura. The *haor* area experiences two major types of flood: early or flash flood and monsoon flood. The *haor* areas are frequently affected by the flash floods due to hilly topography and steep slope of the rivers draining the area. The quickly run-off water from elevated upstream catchments (e.g. elevation of Cherrapunji is 1470 m from sea level) loses the flow velocity when draining over the *haor* areas as the elevation of the area is only 2.5-5 m. These flash floods spill onto low-lying flood plain lands in the region (Map 6),

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inundating crops, damaging infrastructure by erosion and often causing loss of lives and properties. Climate change is exacerbating the situation. Flash floods are most common incidence from April to June and from September to October. However, most crop loss is occurred due to early flash flood that damages the nearly matured or semi-matured *Boro* rice (Image 3) during mid March through April.

Image 3 Standing *Boro* paddy (semi-mature stage) in a *haor* area.

The first date to enter flood water in to the *haor* is varied from year to year. It is reported that from 12 March to 27 May flood water enter in to the *haors* followed by a flash flood with about 2 to 7 days later (Table 2). Abedin and Khatun (2019) analyzed yearly flash flood record of Sunamganj district since 1990 and found that the devastating flood mostly hits in the month of May. However, a fluctuation is observed in recent years where flash flood is hitting quite earlier might be due to the change in the global climatic pattern. Now a day, the flash flood mostly hits in the middle of April. According to Biswas et al., (2008) flash flood usually hits the *haor* areas after second week of April that is locally termed as *Boishakhi Dhall*. Most of the farmers harvest their *Boro* rice by this time. But only a few days earlier, if a flash flood hit by the first week of April might affect many of the *haor* areas. *Boro* rice is submerged at premature stage, if flash flood hits earlier i.e. the third or fourth week of March which is termed as *Chaitali Dhall*, which causes an irrecoverable damage (Rashid and Yasmeen, 2017). Although early flash flood at premature stage of *Boro* rice during last week of March to first week of April is a rare event, but ever early flash flood hits the *haor* areas through entering flood water in the *haor* earliest on 12 March 2017 when premature *Boro* rice went under water in many parts of the *haor* areas that caused a havoc or huge disaster.

Table 2 Date of flood water flow enter in to the *haor* and consequent flash flood from 1990

Year	Date of flood water entered into the *haor*	Date of flash flood declared in the *haor*
1990	18 March	21 March
1991	22 May	25 May
1992	8 May	10 May
1993	27 April	30 April
1994	30 May	2 June
1995	25 May	27 May
1996	16 March	18 March
1997	22 May	24 May
1998	20 May	23 May
1999	3 May	6 May
2000	28 April	30 April
2001	27 April	30 April

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2002	14 April	18 April
2003	27 May	30 May
2004	13 April	15 May
2005	22 May	25 May
2006	17 April	19 April
2007	25 April	28 April
2008	2 May	5 May
2009	16 April	18 April
2010	17 April	19 April
2016	-	3 May
2017	12 March	28 March
2022	1 April	6 April

Source CNRS, (2009), Bhattacharjee, (2011), Sumiya et al., (2019) and newspapers.

It is revealed from an analysis of quantitative questionnaire survey from affected farmers that flash flood almost persist about two weeks with about four days of uncertainty (i.e. standard deviation) (Figure 3). Therefore, harvest of *Boro* rice could not save from early flash flood when the crop at near mature or semi-mature stage in April. Although the monsoon inundation lasts about 5 months with 5 weeks standard deviation, but the total duration is divided by the several flood thrusts (wave) where a single wave persist about 17 days (Figure 3). A longer monsoon inundation indicates that long durable deep water rice is only the viable solution for *haor* dwellers in *Aman* season, although deep flood thrust is still remained as a challenge for rice cultivation.

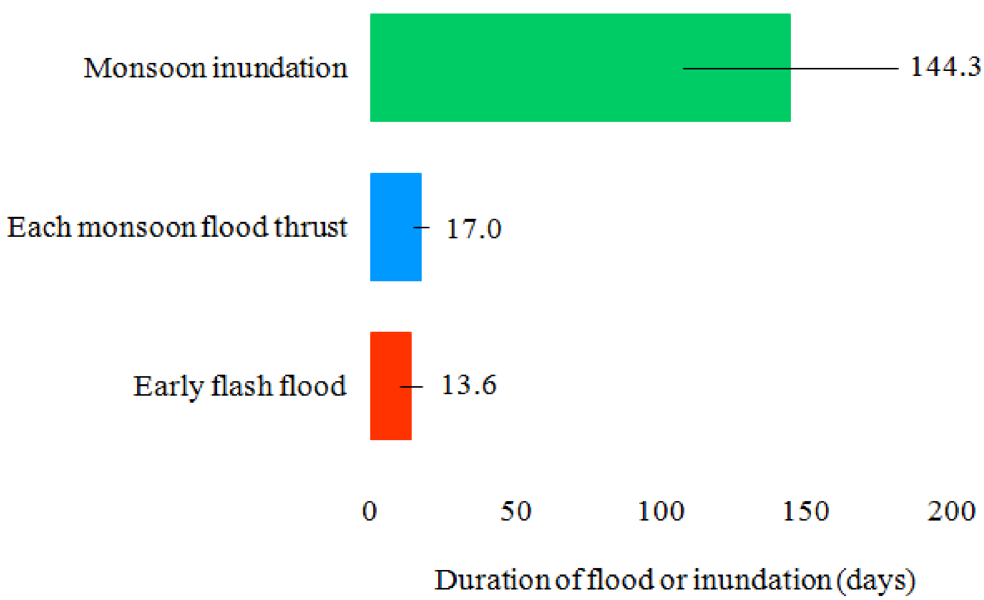

Figure 3 Duration of early flash flood, each monsoon flood thrust and total monsoon inundation in the *haor* areas. Horizontal bars represent the standard deviation (±) of mean as uncertainty of farmer's perception.

Nature of occurrence of flood in *haor* areas

Near about sixty percent of the total farmers believed that early flash flood in *haor* areas occurs more frequently in recent years as compared to that occurred during previous times, although one-fifth of the total farmers believed that the flash flood occurs less frequently (Figure 4). Nevertheless, one-sixth number of the total farmers thought that there is no change of occurrence of early flash flood i.e., frequency of early flood is remained unchanged as that occurred before. According to Rahman, (2019) and Sumiya et al., (2019), *haor* areas of Bangladesh are affected by subversive flash flood frequently. More than forty percent *haor* farmers thought that monsoon flood hits more frequently in their areas, but thirty percent farmers thought that the frequency of monsoon flood is remained unchanged as that occurred in past times. Not surprisingly, about one-fifth number of the total farmers thought that monsoon flood occurs less frequently in *haor* areas (Figure 4).

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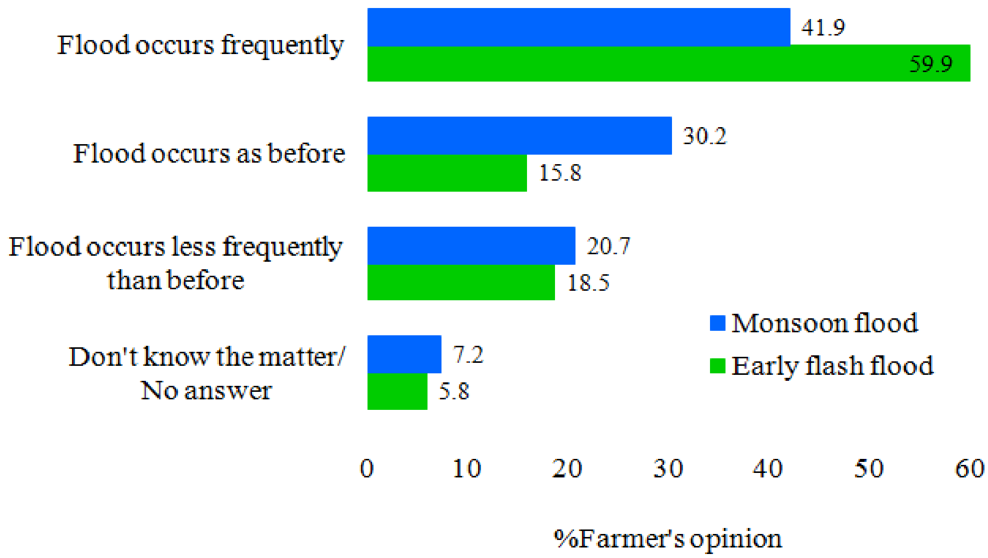

Figure 4 Farmer's opinion on the nature of occurrence of early/flash flood and monsoon flood in *haor* areas.

When heavy rainfall occurs in the hilly Meghalaya, Assam and Tripura regions of India, flood water as the direction of slope quickly moves toward the *haor* areas of Bangladesh through various trans-boundary rivers and eventually enters into the *haors* within 3 to 6 hours (Nowreen et al., 2013; NWS, 2018). In most of the cases, farmers do not get enough time to harvest their standing *Boro* crop which is the only crop of this region. So, farmers might be benefited from early flood warning or forecasting system along with facilitated with mechanical harvesting system for quick harvesting. A general consensus exists that rice crop can be harvested if the 80 percent grains in the panicle become ripe (hard) which is being traditionally practiced in the *haor* areas of Bangladesh. The Department of Agricultural Extension (DAE) officials usually push or force *haor* farmers to cut their *Boro* paddy if this condition is fulfilled on the eve of a forthcoming heavy rain in the area.

According to Bangladesh Meteorological Department (BMD), the frequency of early flash flood hit is increasing. The *haor* areas of Bangladesh are sitting just below the downstream of the highest rainfall peak of the world (i.e. Cherrapunji of India) has to face a rush of flash flood every year. Total rains for 5-6 days beyond 150 mm at the *haor* basin and its upstream catchments which are enough to hit a flood in these areas (Biswas et al., 2008). It is recently found from an analysis of weather data since 1956 of Sylhet region conducted by Rashid and Yasmeen (2017) that early flash flood was occurred in 1964, 1982, 1996, 2003, 2010 and 2017. The rainfall from 29 March to 3 April had been beyond 150 mm for six times in the aforesaid years since 1956. It was 156, 191, 153 and 265 mm in 1964, 1982, 2003 and 2010, respectively. In contrast, rainfall was 625 mm in March 2017, the highest ever and 10 times more than normal rainfall (Rashid and Yasmeen, 2017). The rainfall of 2010 and 2017 can be considered as more grievous. It has been observed that those intense or heavy rainfalls are coming to pass at every 7 years gap. However, the periodicity of early flash flood might be within reach of closer in the years ahead due to global changes in climate.

Some images of damaged dams and embankments or dykes in *haor* areas

Image 4 An embankment collapses in Sunamganj Dharmapasha *Haor* inundating *Boro* crops (adapted from TBS, 2022a).

Image 5 Dam collapse inundates Paknar *Haor* (adapted from New Nation, 2017).

Image 6 Water enters in to Tanguar *Haor* dam in Tahirpur Upazila (adapted from Desk Report, 2022).

Image 7 Flashflood puts *haor* dams at risk (adapted from Staff Correspondent, 2022a).

Image 8 Flash flood water enters in to the *haor* area inundating *Boro* crops (adapted from Independent, 2017).

Image 9 Dam-breach damages *haor* crops in Sunamganj (adapted from TBS, 2022b).

Image 10 A dam is repairing in Khalijuri upazila of Netrokona to protect *Boro* paddy from flash flood (adapted from Daily Sun, 2022).

Image 11 People are trying to protect a dam in Bishwambhar upazila of Sunamganj (adapted from Mahmud, 2022).

Damage of flood protection infrastructures due to flood hit in *haor* areas

Flood water enters in to the *haors* through breeching the dams and embankments or dykes in some places (Images 4-7) and overflowing in others if the flood thrust is too stronger and heavier (Images 8-9). Since the dams and embankments are constructed by the earthen works (i.e. soil), high water pressure easily breeches them. Rain soon exacerbates the situation for cracking and eventually breaking the dams. Since low elevated areas, soil mass is hardly available to build the dams boldly with enough height or repair them quickly or easily in time (Images 10-11). The Bangladesh Water Development Board (BWDB) and the Local Government Engineering Department (LGED) construct and being maintained these flood protection dams and embankments. But the main problem is that the construction of these engineering or civil works are mostly unplanned that ignored the geological and hydrological natures of the *haor* areas and socio-cultural features of the people living therein.

Although the rain and the deluge water from the upriver are the main evil-doers, the settlers also criticize the concerned executives of the BWDB for not completing the erection or repair works of *haor* dykes in advance, which is why the dams or riverbanks gave way to the force of water and give rise to the flood (Roy et al., 2017). Additionally, well order keeps an eye on and overseeing of embankment's refurbishing efforts are absent. After the flash flood of April 2017, the culpability of embankments was

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unwrapped and also call attention to what has to be accomplished to safeguard the growing *Boro* paddy of the *haor* areas (Ray, 2022).

Weak river administration and disturbed water flow

The *haor* farmers urged to authority for dredging the rivers and canals in regular basis to ensure their normal flow so that flood situation could not get worse (Figure 5). They also demanded to construct high dams in their areas so that high flow from rivers could not easily enter into the cropland. The dams should be facilitated with proper sluice gates and their timely maintenance facilities. If so, the river flow can be utilized when growing crops need water in the one way, and the said flow towards the *haors* could be stopped in the time of flooding on the other.

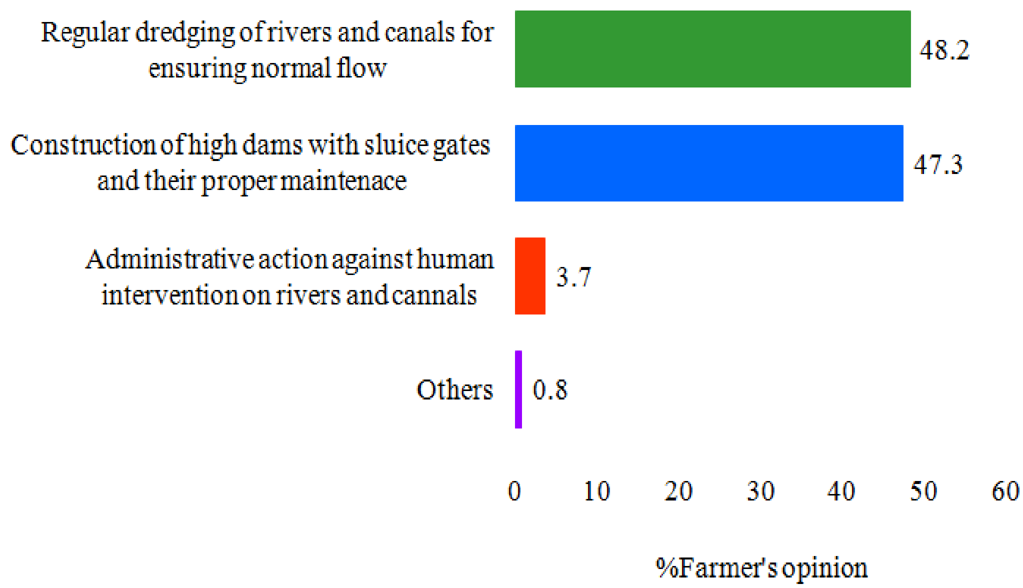

Figure 5 Farmer's expectation from government to keep *haor* agriculture floood free.

Besides the nature of dykes and dams, the ability to discharge the surplus water from the *haor* floodplain areas is also of paramount importance. Water-draining capability of the rivers is reducing fast-moving not only for the reason that of nonstop siltation but also due to the narrowing of the river breadth. The Jadukata River for example, near Bangladesh-India border has substantially narrowed down about 100 metre from 168 m in 2004 to just 68 m in 2017 (Ray, 2022). The Meghna River, which mainly discharges waters from the *haor* region, has both silted up and shrunk at Bhairab Bazar of Keshoreganj district. As a result, the river's ability to discharge the water from the *haor* areas is no longer as fast as it was drained the water before.

So, it is obligatory to dislodge intruders who have erect unauthorized structures in the space of rivers or river banks. Carry out of regular dredging works is also essential in order to speed up the discharging or draining capacity of the rivers in the *haor* areas. If this is succeeded, the stouthearted rivers might discharge the excessive water from the *haor* areas swiftly to drop down it to the Bay of Bengal. However, if the recurrence of flood events takes the edge off as a consequence of sea level rises and other circumstances in relation to climate change, this may not discourse the drawback. If this is the case, the *Boro* paddy that can be harvested about 15 to 20 days earlier have to be shortly developed and introduced for widespread cultivation in the *haor* areas (Awal, 2022 a, b; Ray, 2022).

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Some images of damaged or spoiled *Boro* crops due to early flash flooding in *haor* areas

Image 12 Flash floods damage crops in Sunamganj *haors* (adapted from UNB Dhaka, 2022).

Image 13 Boro crop damages due to flash flood in *haor* areas (adapted from Staff Correspondent, 2022b).

Image 14 Farmers harvest half-ripen *Boro* crop as flash flood hits in Chaptir Haor, Derai, Sunamganj (adapted from Rahman, 2022).

Image 15 Flash floods damage crops worth BDT 100 crore in Sunamganj *Haors* (adapted from UNB Sunamganj, 2022).

Image 16 Farmers harvest submerged semi-matured *Boro* rice in flash-flooded *hao*r (adapted from Staff Correspondent, 2022c).

Image 17 Farmers collects submerged semi-matured *Boro* rice from flash-flooded *haor* (adapted from Zaman, 2017).

Image 18 A farmer holding some *Boro* plants after cutting them from an inundated *haor* field. They can do now with the paddy is use it as fodder (adapted from Roy et al., 2017).

Image 19 Farmers taking away half-ripe *Boro* paddy from flash-flood inundated *haor* fields (adapted from Roy et al., 2017).

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Damage of crops and agricultural commodities in *haor* areas – an early flash flood hit in 2017 as example

Flash flood is occurred every year in various places of *haor* region with different magnitude of damages of *Boro* paddy (Images 12-19) and other agricultural commodities. However, historical damage is occurred due to the early flash flood that hit during March-April of 2017 which turns the situation to a disaster quickly. Out of 7 *haor* districts, six (except the Brahmanbaria district) were affected by early flash flood with severe damage in the Sunamganj district. Thirty one percent of total population that covers more than a million of households and 0.9 million farmers are directly affected (Table 3). *Boro* paddy grown in more than 0.4 million hectares of land are inundated or damaged anyway. Some paddies near to mature stages are collected by the farmers from the inundated land with the help of boats. Overall 80 to 90 percent *Boro* paddy is damaged and not harvested or collected at all (Haque, 2022). Total damage of *Boro* is estimated to more than a million metric tons (MT) of paddy (unhusked grain) accounted to 332 million of Bangladesh Taka (BDT). Center for Policy Dialogue (CPD) estimated 4.7 million people who are affected due to flood havoc with damaged *Boro* paddy accounted to 1.6 million MT. CPD's estimation is closed to Author's figures. Based on Ministry of Agriculture's calculation, the *haor* areas lost around 0.8 million MT of *Boro* rice due to 2017 flash flood (Siddique, 2017) which is lower amount than the Author's estimation. However, Barakat et al., (2019) estimated somewhat higher crop loss worth to 439 million BDT.

Table 3 Loss occurred at a glance in *haor* districts due to early flash flood in March and April of 2017 (Source: D-Form information from Department of Disaster Management, Government of People's Republic of Bangladesh)

Haor district	No. of population affected [a]	No. of household affected	No. of farmer's affected	Inundated or damaged crop land (ha)	Damaged *Boro* paddy	
					Amount (MT) [b]	Money (million BDT) [c]
Sunamganj	1,599,950 (65)	325,990	315,084	131,285	449,159	108
Sylhet	850,080 (25)	212,520	105,353	64,438	220,459	53
Habiganj	439,400 (21)	87,880	87,880	56,560	193,506	46
Moulvibazar	424,775 (22)	85,354	49,193	21,513	73,601	18
Netrokona	743,494 (33)	167,180	167,180	69,710	238,495	57
Keshoreganj	609,924 (21)	152,481	152,481	61,207	209,404	50
Total	4,667,623 (31)	1,031,405	877,171	404,713	1,384,624	332

[a]Figure in the parenthesis indicates the percentage of population affected in the said district.

[b]Eighty to ninety percent (85% used for estimation) *Boro* paddy was either damaged or not harvested (collected) due to 2017 flash flood havoc (Haque, 2022), and average national yield of *Boro* paddy was 4.025 MT/ha in 2017 (BBS, 2017).

[c]Procurement price of *Boro* paddy by the Government of Bangladesh after 2017 flash flood havoc was BDT 24/kg. Based on Ministry of Agriculture's calculation, the *haor* areas may lose around 800,000 MT of *Boro* rice in 2017 (Siddique, 2017) which was close to Author's assumption (849,897 MT). Grey box represents Author's estimation rather than D-Form information.

Official estimates indicate that the April 2017 flash flood caused the loss 1.12 million cows and buffalos, 270 thousand goats and sheep and 3.24 million ducks and hens, plus the loss of 215 thousand MT of fish (Table 4). The figures are near to that reported by FAO (2017), however some researchers reported quite different estimates or reported the data from some specific pockets of interest rather than the entire *haor* areas (Akash, 2017; Mondal et al., 2019). The hydrogen sulphide and ammonia gases, and water acidy (as water pH became lower in the situation) formed due to the rotten paddy in logged water, and concomitantly fall in oxygen level in the water (as ammonia gas replaces the dissolved oxygen) as possible reasons behind the deaths of fishes (ideal pH level for most freshwater tropical fishes between 6.8 and 7.8 i.e. slightly alkaline) (Dhaka Tribune, 2017; Mondal et al., 2019), although the exact inducement is, as yet, undisclosed. Rotten fishes befoul the *haor* habitat further and unendurable effluvium as a consequence of the go sour affects the ducks in the areas.

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Table 4 Information on damage to livestock, cattle, poultry, water body and fish as received from Ministry of Fisheries and Livestock

Haor district	No of loss of livestock, cattle and poultry						No of water body damaged	Fish damaged (000'MT)
	Cow	Buffalo	Goat	Sheep	Duck	Hen		
Sunamganj	361,000	1,250	68,500	32,450	1,210,500	962,000	23	50
Sylhet	249,574	11,763	28,797	41,729	2,120,621	401,100	8	21
Habiganj	140,324	1,092	22,640	9,221	1,019,903	517,354	0	0
Moulvibazar	67,022	15,072	21,865	2,719	89,756	266,890	1	25
Netrokona	139,858	533	40,118	2,053	1,017,495	491,096	14	119
Keshoreganj	132,388	0	0	0	513,300	0	0	0
Total	1,090,166	29,710	181,920	88,172	597,175	2,638,440	46	215

Source DDM Report on Damage Information and Relief Distribution on Flash Flood, April 28, 2017.

Barakat et al., (2019) reported a total loss worth to 452 million BDT due to early flash flood in 2017 in *haor* areas due to the damage of crop, fish and fodder (rice straw). Due to damage of main crop (*Boro* paddy), most of the day labourer became jobless shortly that accounted to 263,808,000 person day (Nirapad, 2017) which is obviously a great loss especially for poor who have no other alternative to support livelihood. However, the entire loss including all economic sectors due to 2017 flash flood and consequent disaster is not passed on yet, so far.

Home adaptation by *haor* dwellers to cope flood hit

Eighty eight percent *haor* dwellers use raised plinth against devastating flood while rest of the dwellers transfer the household members else during the time of flooding if their homes are not elevated sufficiently (Figure 6). Plinth rising is a common strategy to cope with the flood risk in *haor* and other flood prone areas of Bangladesh (Awal, 2013, 2015; Abedin and Khatun, 2019). The main challenge of plinth rising is the lack of soil mass in *haor* areas as the elevation of the areas are quite lower.

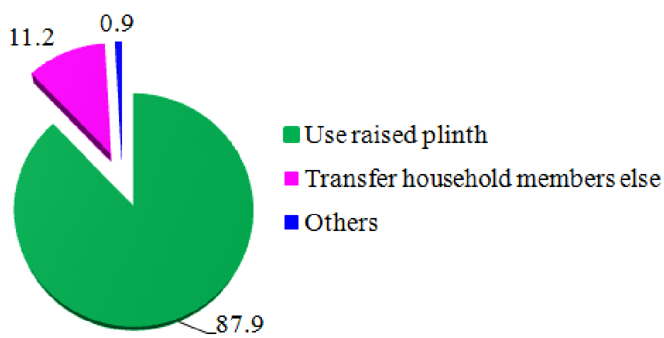

Figure 6 Percent farmer's opinion on home adaptation during devastating flood event.

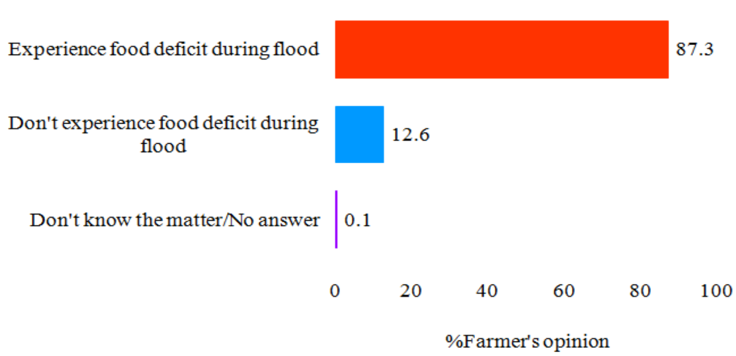

Figure 7 Experience of food crisis if crop loss occurred due to flood hit in *haor* areas.

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Occurrence of food crisis due to crop loss and strategy to cope

Flash flood hits the *haor* regions at a time when the standing *Boro* paddy remains at near to reap and the farmers wait to cut them. Stock of the food grains from previous harvest is no longer available in the houses of the farmers when flood hits and thus they go through a miserable situation because of the scarcity of food.

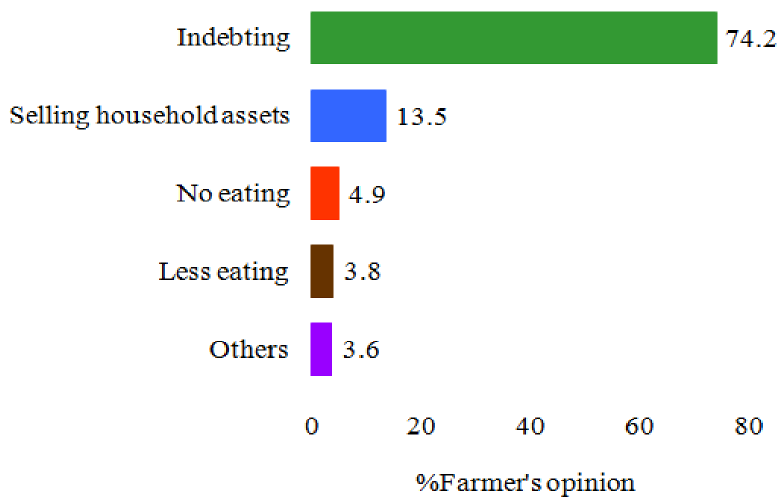

Figure 8 Farmer's opinion on coping strategy for food crisis if crop loss occurred due to flood.

More than eighty seven percent farmers experienced food crisis if crop harvest is failed due to flood hit in *haor* areas (Figure 7). That means the said percentages of farmers is marginal and have no saving to cope with crop loss due to flood hit. Of this percentage of the *haor* dwellers, about three-fourth number became indebted and 13.5 percentage selling out household assets like jewelry, cattle's, etc to support food meal of the household members (Figure 8). A few percentages of very marginal farmers live with either no eating or less eating with compromising the quality of the diets. Dey et al., (2021) also found that *haor* dwellers change their usual food habits, roughly one-third of households consumed two instead of three meals per day, 53 percent households adapted and consuming to less food and 16 percent had low nutritious food due to the scarcity of food. The lack of money and loss of main *Boro* crop were the main contributing factors of crisis for *haor* dwellers. In the *haor* area, the socioeconomic and livelihood condition are much different from the other parts of the country and *haor* flood leads to reduce the farmer's economic condition that are totally depend on agriculture (Kamruzzaman and Shaw, 2018).

Flash flood frequently poses severe threat to *haor* dwellers in Bangladesh. Occupation and income of the poor are the two most crucial sectors on which flood have significant impacts. Flash floods not only force people to change their occupations but also negatively affect people's income. Occupation of majority of the respondents were involved with farming and day laboring, respectively based on *haor* resources but during flash flood most of them turned into seasonal fisher (Abedin and Khatun, 2019).

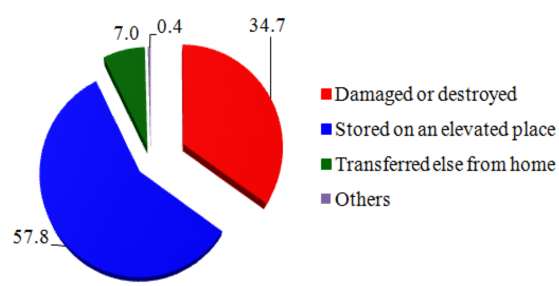

Figure 9 Percent farmer's opinion on fate of stored food grain during devastating flood event.

Fate of storage food grains of *haor* dwellers to flood hit and coping strategy

To escape from the devastation of a widespread flood, more than fifty percent *haor* dwellers stored their food grains at elevated places in their houses (Figure 9). This technology may save their stored food grains especially staple rice during flooding time. About seven percent farmers transfer their food grains else and returned these after receding the flood water. However, stored food

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grains of more than one-third farmers are spoiled due to flood hit in *haor* areas. It results acute food crisis during post flood time especially who are poor and marginal people in the *haor* areas. Therefore, more than three-fourth portion of the total farmers in *haor* areas expect the construction of food godown through government initiative where the affected farmers could keep their food grain during the time of flood (Figure 10). Near to a one-fifth number of farmers expressed that the grain godown can also be built by community or cooperative efforts.

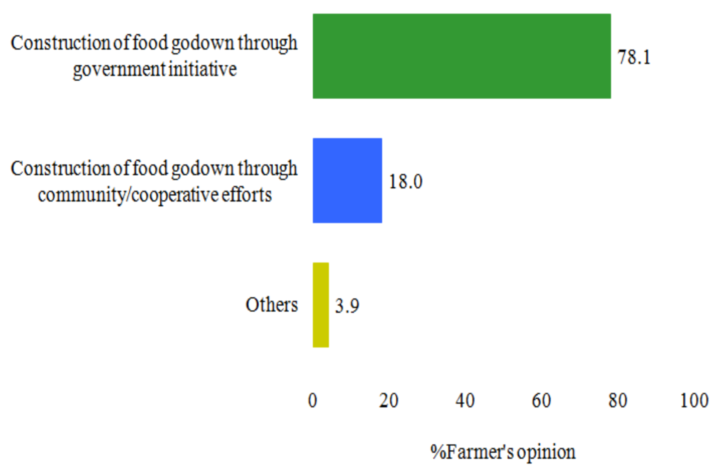

Figure 10 Farmer's opinion to save damaged food grains due to flood events.

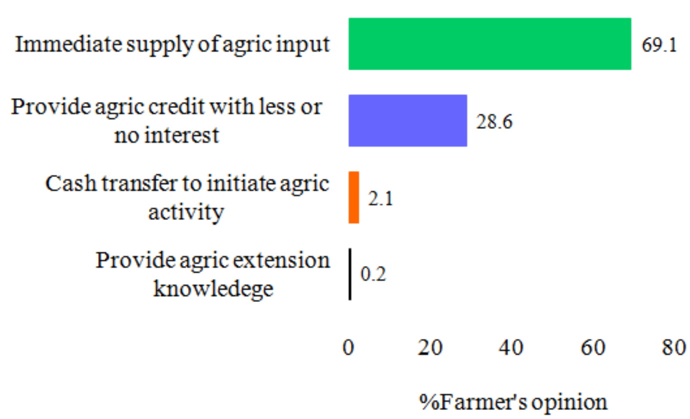

Figure 11 Farmer's demand in the *haor* areas following the crop loss due to a flood hit.

Expectation from government if crop loss occurred due to flood hit

To maintain production flow in favour of the *haor* dwellers, near to a seventy and thirty percent farmers would like to respectively get the agriculture inputs and interest free credit or loan from the government when standing crop is lost following a devastating flood hit (Figure 11). Although a few percentage of farmers would like to get cash incentives or extension knowledge of agriculture practices from the authority soon after a flood shock. These initiatives could help the farmer's capacity or confidence to absorp the flood shocks for starting the new crop cultivation practices after crop damage by flood shock. Some of these activities from the government of Bangladesh are also in place through pertient departments. But it should be ensured timely with poper monitoring activities and the porgrammes should be widended to cover most of the growers in the *haor* areas.

4. CONCLUSION

Rains occurred in the upstream zone like Meghalya, Aasam and Tripura of India, and in northeastern districts of Bangaldesh are responsible to create flood in the *haor* areas. The flood protecting earthen dams or embankments or dykes are very weak against water pressure that initiates crake and eventually collapses them lead to enter run-off rain water in to the *haor* and causes flood. The soil mass is hardly available to build the dams boldly or repair them quickly in time. Early flash flood inundates the standing semi-ripen *Boro* paddy along with a great loss of fodder (rice straw), fish, cattle, duck, poultry etc and thus labour hours in the region and thereby jeopardizes the life and livelihood of the people therein. Advancement of *Boro* season could escape the early flash flood.

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Alternatively, early flood warning and forecasting systems for saving *Boro* paddy might be devised. The affected farmers expect loan or credit with zero interest system and agricultural input and extension supports from government to shortly start the farm activities soon after a flood hit.

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Ethical approval

Not applicable

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Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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