National Resilience Programme

Concept Note on

Dynamic Flood Risk Model under Flood Preparedness Programme

Department of Disaster Management

Ministry of Disaster Management and Relief

Developing Institutional Framework of Flood Preparedness Programme

Development of Dynamic Flood Risk Model (DFRM)

March 2021

Department of Disaster Management

Ministry of Disaster Management and Relief

Executive summary

Bangladesh is one of the most vulnerable countries in the world due to hydro-geological and socio-economic factors such as geographical location, topography, extreme climate variability, high population density, poverty incidence and heavy dependency of agriculture on climate. Under the National Resilience Programme (NRP) of the Government of Bangladesh with the technical assistance of United Nations Development Programme (UNDP), UN Women and United Nations, the Institute of Water and Flood Management (IWFM) BUET has assigned to develop a sustainable strategy for community-driven Flood Preparedness Programme (FPP) through inclusive, gender-responsive disaster management. Focusing to build a Flood Resilient Community through enhancing flood early warning and preparedness, improved coping and response mechanisms in line with the changing trends of the flood incidents, in Jamalpur and Kurigram district, a Dynamic Flood Risk Model (DFRM) has been developed.

This community-based warning system (DFRM) aims to improve the national level early warning disseminated by FFWC and generate local flood event data (inundation area, depth, velocity, duration and risk). The model combines the flood information generated by two-dimensional numerical simulation, from the closed scenario of the current situation and gives inundation, hazard and risk information to the local community. Twenty five scenarios have been generated using the available time series hydrologic information from 1956-2020. It is hoped that the information it generates will facilitate the administrators and planners to identify areas vulnerable to flood hazards and will enhance the capability to respond and recover. At the same time, the model generated flood hazard and risk maps can support planning and development by identifying high-risk locations and steering development away from these areas.

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1 Introduction

Bangladesh is one of the most vulnerable countries in the world due to hydro-geological and socio-economic factors such as geographical location, topography, extreme climate variability, high population density, poverty and heavy dependency of agriculture on climate. The damage caused by a flood is relatively high as one-fifth to one-third of the country is annually flooded by overflowing rivers during the monsoon. Extreme rainfall within the country also exaggerates the flooding situation during the same period. Though normal floods are considered a blessing for Bangladesh-providing vital moisture and fertility to the soil through alluvial silt deposition in floodplains, moderate to extreme floods are of great concern, as they inundate large areas (more than 60% of the country are inundated in large flood events) and cause widespread damage to crops and properties (Rahman and Salehin 2013; Chowdhury et al. 1997). Two-thirds of the country's territories are less than 5 meters above sea level. The population is expected to rise to 259.9 million by 2100. Furthermore, Bangladesh is ranked 142 of 187 on the Human Development Index, indicating a low level of human development. Among the countries affected by climate change, Bangladesh, with its strong exposure to natural hazards, is ranked 10 out of 180 in the World Risk Index indicating high exposure to natural disasters with a low quality of institutions and infrastructure management capacity (Forster et al. 2019). The socio-economic impact of floods is profound; the flood-prone zones represent areas with the highest incidence of the extreme poor, and the number of poor living in high flood risk areas is on the rise. To reduce such huge vulnerability of flood in the path of achieving the Sustainable Development Goals (SDGs) by 2030, the Government of Bangladesh under the National Resilience Programme (NRP) of the with the technical assistance of the United Nations Development Programme (UNDP), UN Women and United Nations assigned the Institute of Water and Flood Management (IWFM) BUET to develop a sustainable strategy for community-driven Flood Preparedness Programme (FPP) through inclusive, gender-responsive disaster management. Focusing to build a Flood Resilient Community through enhancing flood early warning and preparedness, improved coping and response mechanisms in line with the changing trends of the flood incidents. This research has been focused on the local community of Jamalpur and Kurigram district (

Fig. 1). The overall aim of the research is to build the Flood Resilient Community through enhancing flood early warning and preparedness, for improving community resilience by creating replicable, cost-effective methods for local disaster risk reduction and risk management.

2 Objectives and the expected outcome

The overall objective of the study is to enhance the resilience of the community in the way of Build Back Better (BBB) through Flood Preparedness Programme (FPP).

Specific Objectives

1. Formulating a sustainable strategy for community-driven Flood Preparedness Programme (FPP)
2. Developing community-driven flood risk and resilience model that need to be tested under FPP
3. Customize flood warning system including a flood inundation model based on the river water level, flood staging and its dissemination strategy to the end-users
4. Assist partner NGO (nominated sub-consultant) to implement community-based FPP model
5. Strengthening the flood early warning system and its dissemination at the community level
6. Assist PNGO for raising community awareness on flood preparedness
7. Developing an institutional framework of from community to national level
8. Assist PNGO in developing policies for advocating FPP

The expected outcome of the study to generate risk-based flood early warnings at the community level through the development of the Dynamic Flood Risk Model (DFRM). It is expected that the model generated information that will enhance the communities' flood preparedness and emergency response mechanism and thus will help to grow the more resilient community.

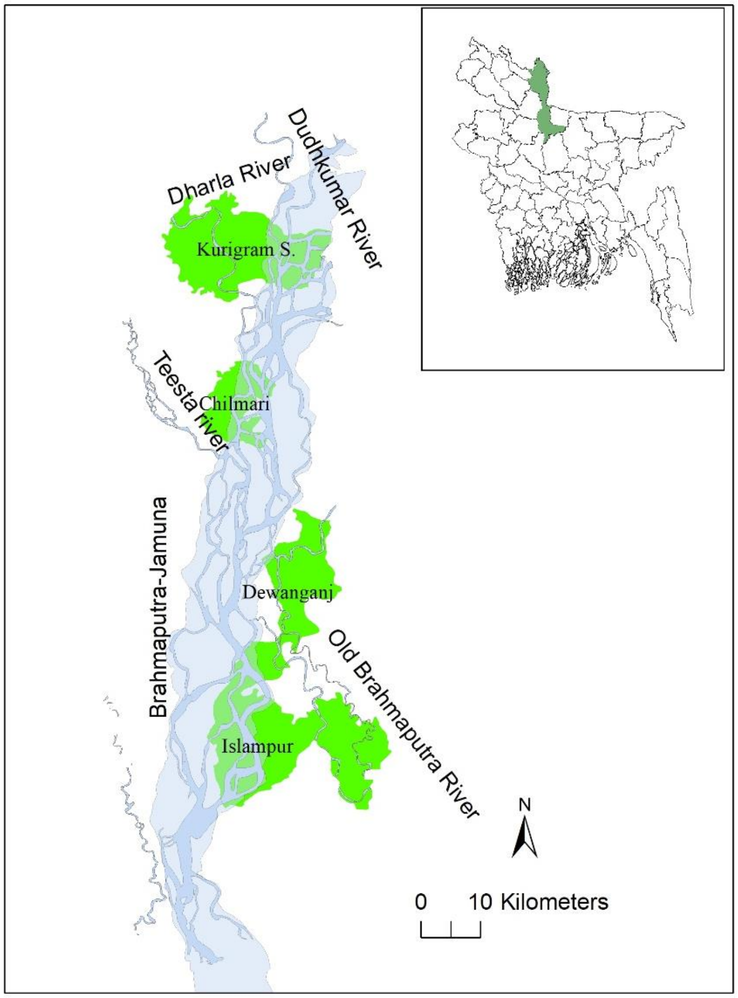

Fig. 1: Map of the study area

3 Geographical and Risk context of Kurigram and Jamalpur

This study aims towards improving community resilience by creating replicable, cost-effective methods for local flood risk reduction and management through Flood Preparedness Programme (FPP). Focusing to build a Flood Resilient Community through enhancing flood early warning and preparedness, improved coping and response mechanisms in line with the changing trends of the flood incidents, two field visits were performed in January and November 2020 in Jamalpur and Kurigram district (Fig. 2). The aim was to find out the existing flood forecasting systems, dissemination practices, and prioritizing their choices in early warning systems including dissemination processes in the study area.

3.1 Geographical context

The study was conducted in one of the villages of Kurigram district under the Rangpur division which is in the northern part of Bangladesh along the border of India. There are 9 upazillas in Kurigram district. Chilmari Upazila of this district is situated in between 25°26' and 25°40' North latitude and between 89°38' and 89°48' East longitude and is highly vulnerable to upstream floods and riverbank erosion. It is located by the Indo-Bangladesh frontier. Chilmari Upazila is bounded by Ulipur Upazila on the north, Char Rajibpur and Sundarganj Upazilas on the south, Raumari and Char Rajibpur Upazila on the east, Ulipur and Sundarganj Upazilas on the west. It has 6 unions, 58 mouzas and 144 villages. Among the six unions, Ashtamirchar union is the most flood vulnerable union as it is intersected by the mighty Brahmaputra river. There are 23 Mouzas (under Ashtamirchar union where total population is 17701 with 23.5% literacy rate. Char Mudafat Kalikapur Village of Char Mudafat Kalikapur mouza of this union is found out as the most flood-prone area. And that’s why it has been selected as the study area. The number of the household of Char Mudafat Kalikapur Mouza is 715. According to BBS 2011, the Total population is 2963 which is 16.74% of Astamirchar union. The literacy rate is 21.9% which is lower than the literacy rate of Union. The demographic information of the surveyed area is listed in Table 1.

Table 1: Demography of study area (BBS 2011)

	Ashtamir Char	**Patharsi**
Total area (Acres)	18,528	8,451
Population	17,701	28,009
Household	4,077	7,547
Density (per km^2)	236	819
Literacy rate (%)	23.5	39.7
Sex ratio	96	97
Mouza (no.)	13	11
village (no.)	14	12

Patharsi is a union under Islampur Upazila of Jamalpur District located between 24°34' and 25°26' North and between 89°40' and 90°12' East with a total area of 8,451 acres. The Zila shares an international border with the Indian state of Meghalaya in the North East. Geographically Jamalpur Zila is a river floodplain in the left bank of Brahmaputra river and situated beside the old Brahmaputra river. There are 7 Upazilas on which 4 Upazilas are directly in riverside highly vulnerable for riverine flood in every year. As there are no embankment along the left bank of Brahmaputra river, the flood water coming from upstream spread out rapidly in the floodplain. So,

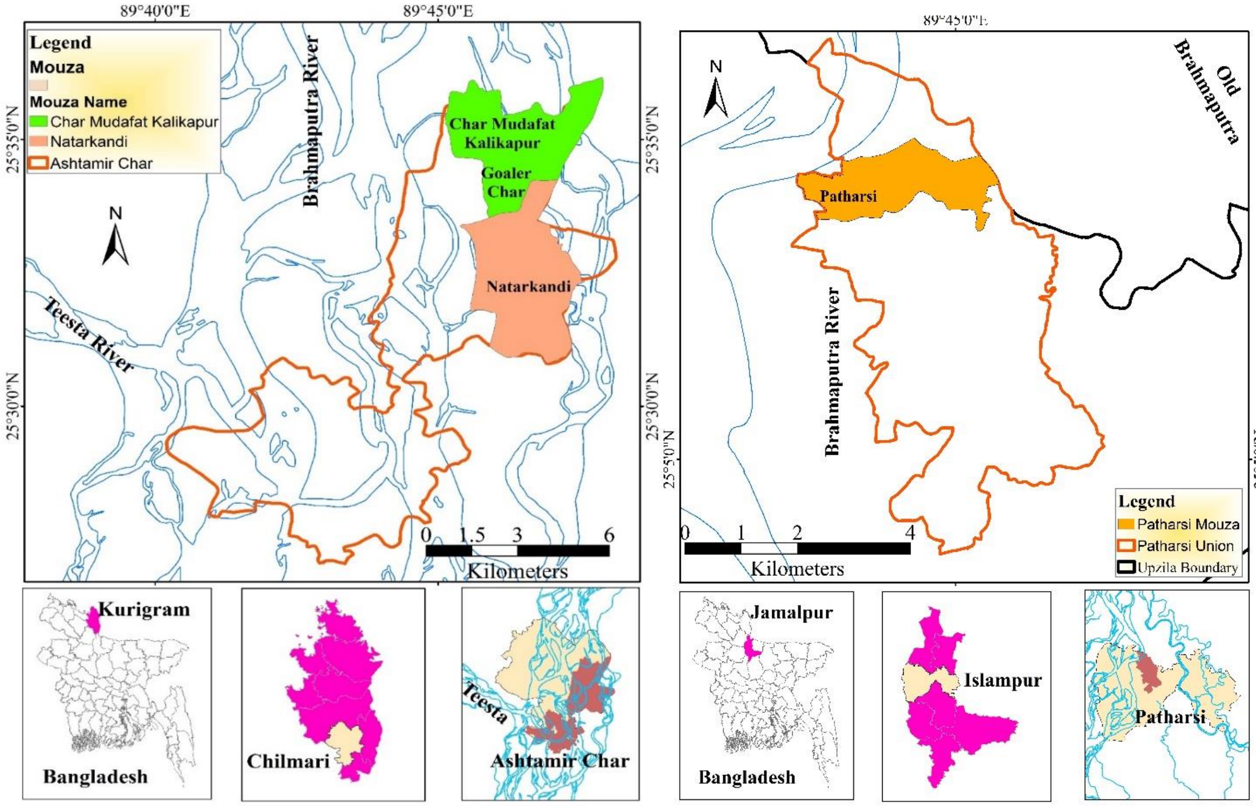

Fig. 2: Ashtamir Char in Chilmari Upazila & Pathorshi in Islampur Upazila

the flood is a regular hazard in this Zila. With flood, river erosion is a major problem that occurs in Dewanganj and Islampur Upazila. Most of the Upazilas of Jamalpur are highly fertile with a regular inundation every year. So, rice production hampers a lot due to the monsoon flood. This event fluctuates the socio-economic conditions of the rural people involved with agriculture especially rice production. The study area is Pathorshi village of Pathorshi mouza in Pathorshi Union near the Brahmaputra river in Islampur Upazila. Most of the people is engaged with agriculture and some of them are involved with capture fishing as a secondary occupation. The monsoon flood hit the area every year and hampers the Amon rice production. The area is inundated 2-3 times in every monsoon. But, in 2020 the recurrent flood occurs 4-5 times in a single monsoon period. It costs a huge loss of their Amon production and falls their economic condition.

3.2 Risk Context

In IPCC AR5, the risk is defined as the results of the interaction of hazards with vulnerability and exposure of human and natural systems (IPCC, 2014). Where vulnerability AR5 is computed as a linear relation of sensitivity and adaptive capacity. The formulae for risk and vulnerability are discussed in section 6.1.

In this study, the following exposure and hazard domains have been used.

Exposure Domain	Hazard Domain (Flood)
Population Density	Flood pattern
Household Size	Water Depth
Total number of para/mouza/village	Flood Velocity
Kacha and Jhupri houses	Flood Duration

Selection of Indicators

Indicators for different capitals have been selected based on reviewing literature, expert's judgments and data availability. The following indicators have been used for different capitals:

Human Capital

i. Literate People
ii. Employed people
iii. Male : Female
iv. Capable people
v. People access to the tube well

Social Capital

i. Literate People
ii. Employed people

Physical Capital

i. Religious place (Mosque)
ii. Educational Institution
iii. Community Clinic
iv. Shelter Centre
v. Puka and Semi paka house
vi. Tube well

Financial Capital

i. Number of HH with access to microcredit

ii. Growth Center
iii. Employed People
iv. No. of market/hat

Natural Capital

1. Tube wells

Human Capital & Vulnerability

Human Capital at Unions

Literate, employed, physically strong and capable people are the human capitals. Again, people's access to tube wells (safe drinking water source) are also been categorized in human capital.

In the following Fig. 3, a human capital map has been shown.

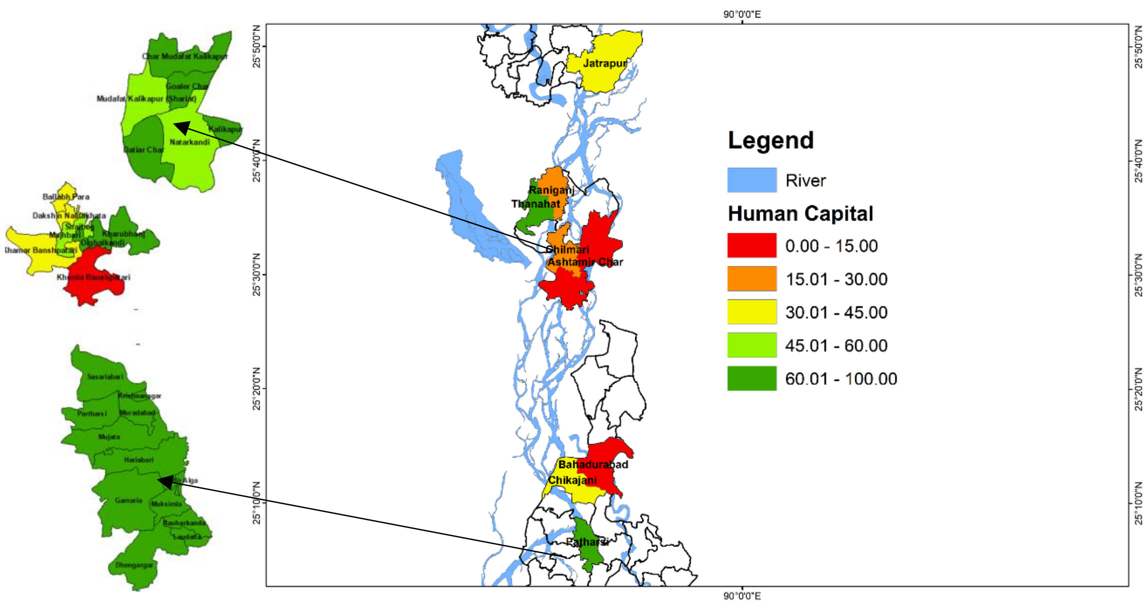

Fig. 3: Human Capital Mapping of union and village level;

Source: Author, 2020

According to the figure, human capital at Ashtamir char union from Kurigram and Bahadurabad union from Jamalpur are critically low. Whereas the condition of human capital at Thanahat union from Kurigram and Patharsi union from Jamalpur is very good.

Human Capital at Villages

Ashtamir Char has 13 mouzas and 14 villages in total. From these only one village namely Khurda Banshpatari has the critical quantity of human capital shown in the above map. Whereas total 7 villages of the union is under very high human capital range. Rest villages have fallen in the range of moderate and high human capital range. So, in this union distribution of human capital among the villages is very uneven. The focus should be given to the specific village (Khurda Banshpatari) in improving human capital. On the other hand, all villages of Patharsi have very high human capital that represents an even distribution of human capital.

Human Vulnerability at Unions

As the concept of vulnerability is just the opposite of Capital the following figure shows the vulnerability for human capital. From the figure below, it is clear that only two unions one from Kurigram and the other from Jamalpur is low vulnerable to flood due to human capital. The unions are Thanahat and Patharsi as these two unions have a good quantity of human capital which has been illustrated above.

And the rest of the unions have high vulnerability having a critical quantity of human capital. So, these unions should be prioritized while on human capital improvement projects.

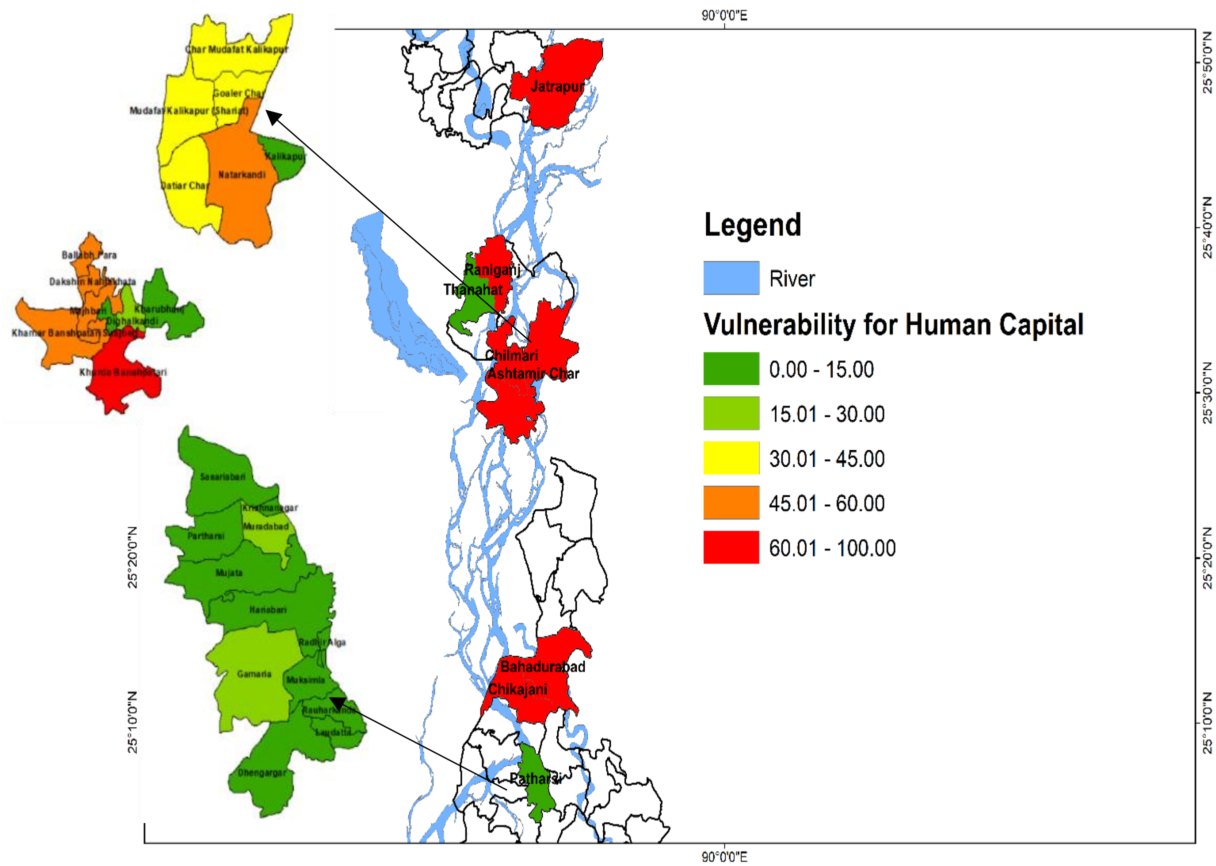

Fig. 4: Human Vulnerability Mapping of union and village level

Table 2: Percentage of human capital and vulnerability

Human Capital/ Vulnerability	**Percentage of area (Human Capital) (%)**	**Percentage of area (Human Vulnerability) (%)**
Very High	18	82
High	22	0
Moderate	8	0
Low	16	0
Very Low	36	18
Total	100	100

Table 2 shows that the percentage of the area having the lowest capital in the whole study area is the highest and that is about 36% whereas that of the lowest percentage belongs to moderate human capital. Again, the percentage of the area having very high human capital is only 18%. This figure of area percentage shows an unsustainable livelihood condition. On the other hand except for 18% area of the whole study area is highly vulnerable to human capital.

Social Capital & Vulnerability

Social Capital at Unions

Literate and employed people are the social assets. As they can be a good leader in any crisis and also they can be a medium of awareness for the whole society. In Fig. 5, the social capital map has been shown.

According to the figure, social capital at Ashtamir char union from Kurigram is critically low. Whereas the condition of human capital at Thanahat union from Kurigram is very good. Again Raniganj and Patharsi union have high social capital and Chikajani, Bahadurabad and Jatrapur union has low social capital. However, Chilmari from Kurigram has moderate social capital.

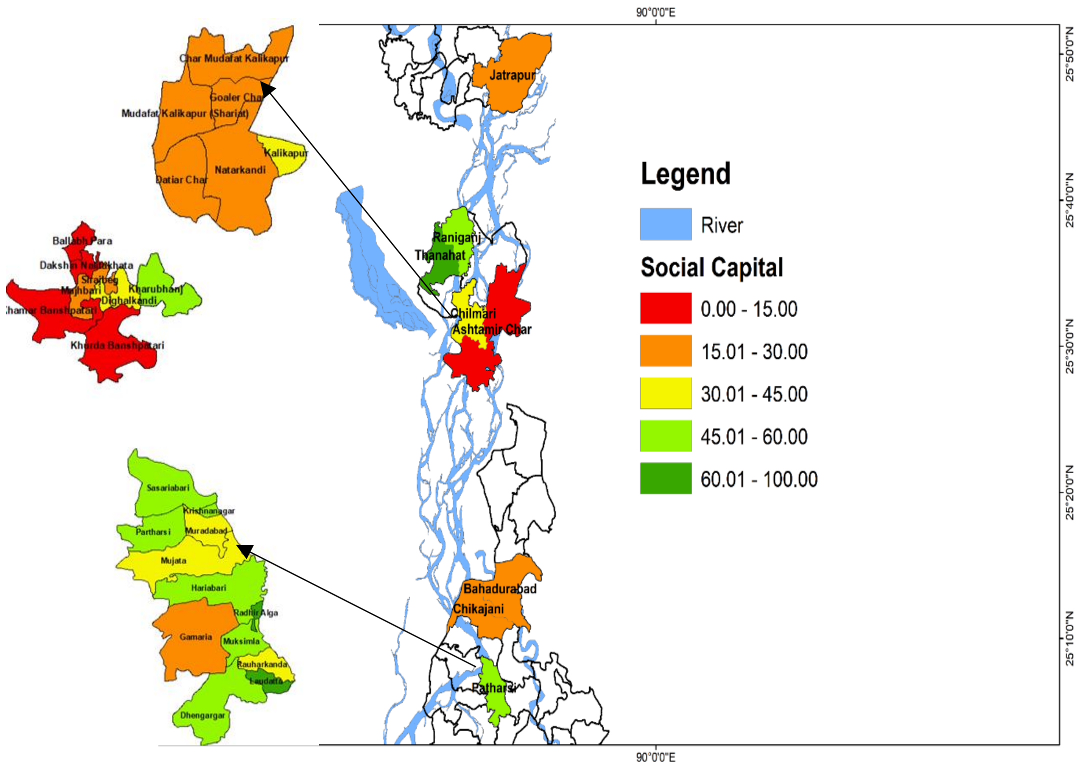

Fig. 5: Social Capital Mapping of union and village level;

Social Capital at Villages

Ashtamir Char has 13 Mouzas and 14 villages in total. From these four villages namely Khurda Banshpatari, Ballabh Para, Dakshin Nalitakhata and Khamar Banshpatar has the critical quantity of social capital shown in the above map. Whereas Kharubhanj village has high social capital. Rest villages are in low to medium social capital range. So, in this union distribution of social capital among the villages is very uneven. The focus should be given to the specific villages in improving social capital.

On the contrary, two villages of Patharsi named Radhir Alga and Laudatta have very high social capital where Gamaria has low social capital. In the rest villages, social capital varies from high to medium. However, in this union distribution of social capital is more or less even.

Social Vulnerability at Unions

As the concept of vulnerability is just the opposite of Capital the following figure shows the vulnerability for social capital.

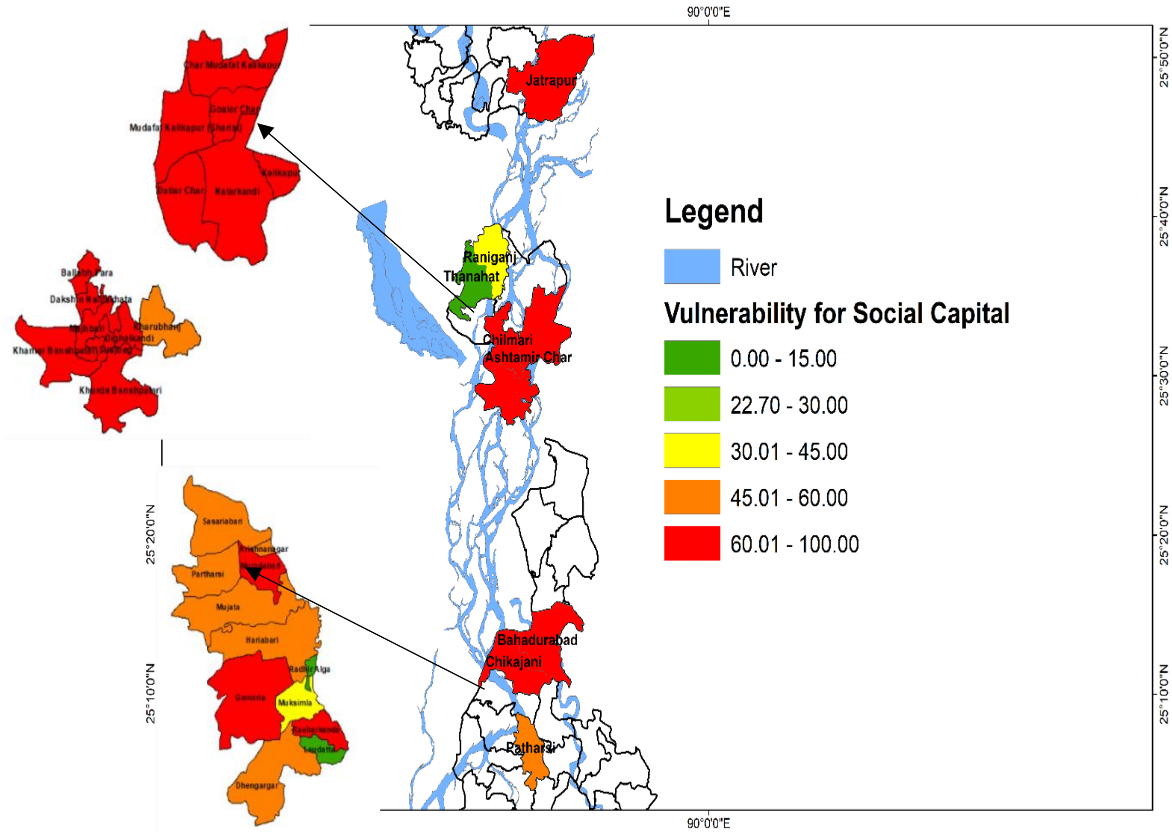

Fig. 6: Social Vulnerability Mapping of union and village level

It is clear that only one union from Kurigram is low vulnerable to flood due to social capital. Again Raniganj from Kurigram and Patharsi from Jamalpur has medium and high vulnerability respectively.

Except these 3 unions, all unions are in very high vulnerability condition. So, these unions should be prioritized while social capital improvement projects.

Table 3 : Percentage of Social capital and vulnerability

Social Capital / Vulnerability	**Percentage of area (Social Capital) (%)**	**Percentage of area (Social Vulnerability) (%)**
Very High	11	74
High	27	10
Moderate	12	8
Low	16	0
Very Low	34	7
Total	100	100

Table 3shows that the percentage of the area having the lowest capital in the whole study area is the highest and that is over 34% whereas that of the lowest percentage (11%) belongs to very high social capital. Again, the percentage of the area having high social capital is only 27%. This figure of social capital shows a poor distribution of social capital over the study area.

On the other side, very high vulnerability covers the maximum portion of the study area and that is over 74% were very low vulnerability present at only 7% area.

Social Vulnerability at Villages

From 14 villages of Ashtamir Char, all villages except one village namely Kharubhanj are highly vulnerable as these villages have the critical quantity of social capital discussed in the above section. Hence, the focus should be given to the whole union in improving social capital.

On the other hand, two villages of Patharsi namely Radhir Alga and Laudatta have very low social vulnerability as these villages have enough social capital discussed in the above section. However, the rest villages are in medium to very high vulnerability range.

Physical Capital & Vulnerability

Physical Capital at Unions

Physical infrastructure such as mosques, schools, community clinic, shelter center, housing condition and availability of tube well is the physical capitals as shown in Fig. 7. According to the figure, the Physical capital at Ashtamir char, Chilmari, and Jatrapur union from Kurigram is critically low having the highest vulnerability. Whereas the availability of physical capitals at Thanahat union from Kurigram and Patharsi union from Jamalpur is abundant. These two unions should have the minimum vulnerability. Again, the rest unions have low physical assets.

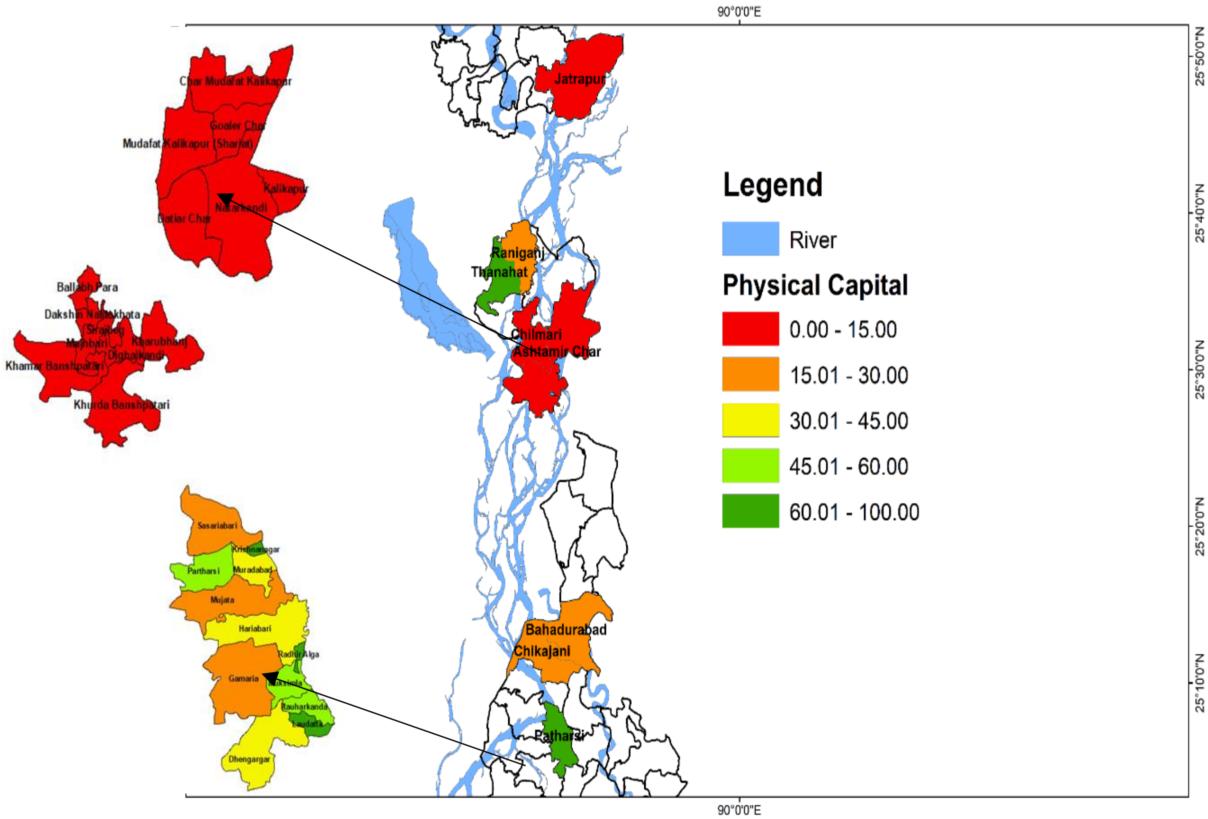

Fig. 7: Physical Capital Mapping of union and village level

Physical Capital at Villages

Among 14 villages of Ashtamir Char, all villages have the lowest physical capital. The reason behind this scenario is locational disadvantages. The accessibility of the union is very low, which influenced the union to lag in every case. The focus should be given to the whole union in establishing physical capitals.

On the other hand, Patharsi union gave a mixed result in physical capital analysis. Krishnanagar, Radhir Alga and Laudatta villages have an abundant number of physical capital. Besides Patharsi, Muksimla and Rauharkanda villages also have high physical capital. However, the rest villages have moderate to low physical capital.

Physical Vulnerability at Unions

As the concept of vulnerability is just the opposite of Capital, the following figure shows the vulnerability for human capital. From the figure below, it is clear that except for two unions one from Kurigram and other from Jamalpur all unions are highly vulnerable to flood due to physical capital. The exceptional two unions are Thanahat and Patharsi as these two unions have a good quantity of physical capital which has been illustrated above. Patharsi union has the lowest vulnerability and Thanahat has that of the moderate.

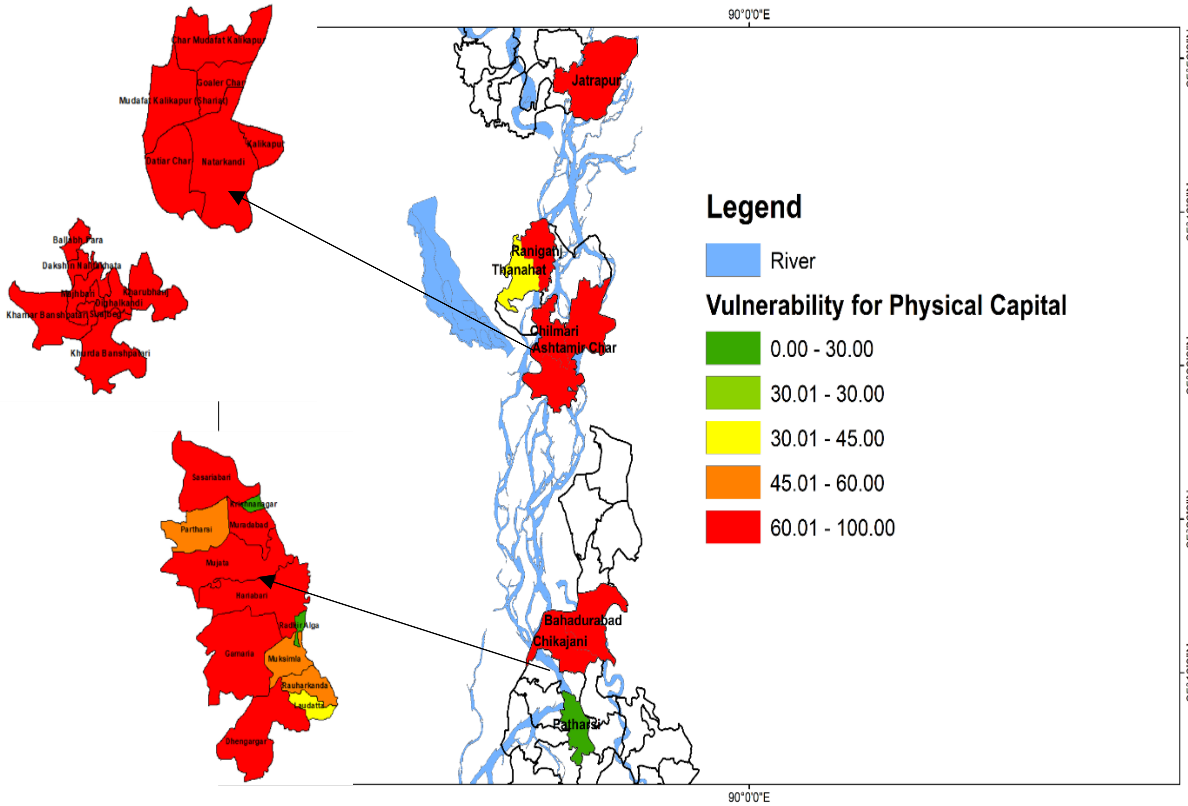

Fig. 8: Physical Vulnerability Mapping of union and village level

Table 4 : Percentage of Physical capital and Vulnerability

Physical Capital/ Vulnerability	**Percentage of area (Physical Capital) (%)**	**Percentage of area (Physical Vulnerability) (%)**
Very High	18	82
High	0	0
Moderate	0	7
Low	29	0
Very Low	53	10
Total	100	100

Table 4 shows that the percentage of the area having the lowest capital in the whole study area is the highest and that is about 53% whereas only 18% area of the whole study area has high physical capital. This figure of area percentage shows an unsustainable livelihood condition. On the other hand except for 10% area of the whole study area is highly vulnerable for physical capital.

Physical Vulnerability at Villages

From 14 villages of Ashtamir Char, all villages is highly vulnerable as these villages have the critical quantity of physical capital discussed in the above section. Locational disadvantages is the main reason for the very low establishment of physical capital. Hence, the focus should be given to the whole union in improving physical capital.

On the contrary, two villages of Patharsi union namely Radhir Alga and Krishnanagar have very low physical vulnerability as these villages have enough physical capital discussed in the above section. However, the rest villages are in the medium to very high vulnerability range.

Natural Capital & Vulnerability

Natural Capital at Unions

No. of tube wells is the only indicator for analyzing Natural capitals as shown in Fig. 9. No of tube wells represent the condition of groundwater. According to the figure, the Natural capital of all unions of the study area is critically low except for two unions. The condition of Natural capital at Thanahat union from Kurigram and Patharsi union from Jamalpur is slightly good.

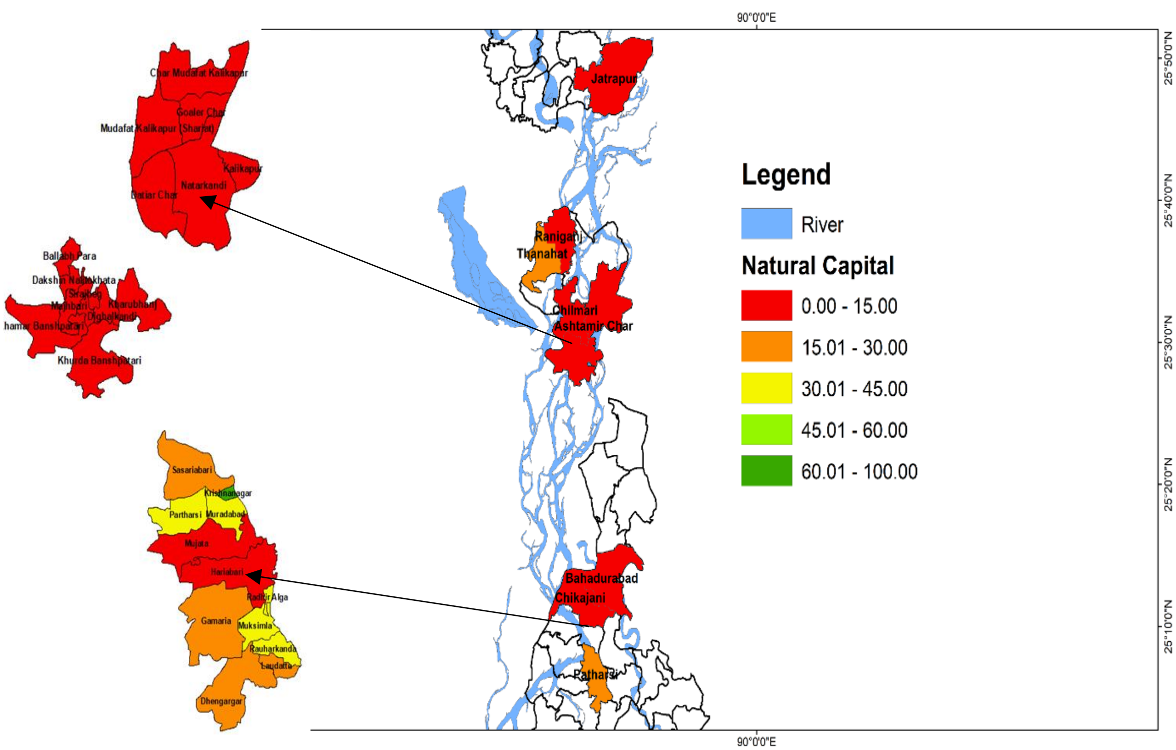

Fig. 9: Natural Capital Mapping of union and village level

Natural Capital at Villages

Ashtamir Char has 13 Mouzas and 14 villages in total. All villages have the critical quantity of natural capital shown in the above map. The focus should be given to this union in improving natural capital.

At the same time, the condition of natural capital at Patharsi union is not that satisfactory. Only Krishnanagar village has abundant natural capital where all other villages have been ranked medium to very low natural capital.

Natural Vulnerability at Unions

As the concept of vulnerability is just the opposite of Capital the following figure shows the vulnerability for human capital. From Fig. 10 below, it is clear that all unions of the study area are highly vulnerable to flood due to natural capital. So, these unions should be prioritized while natural capital improvement.

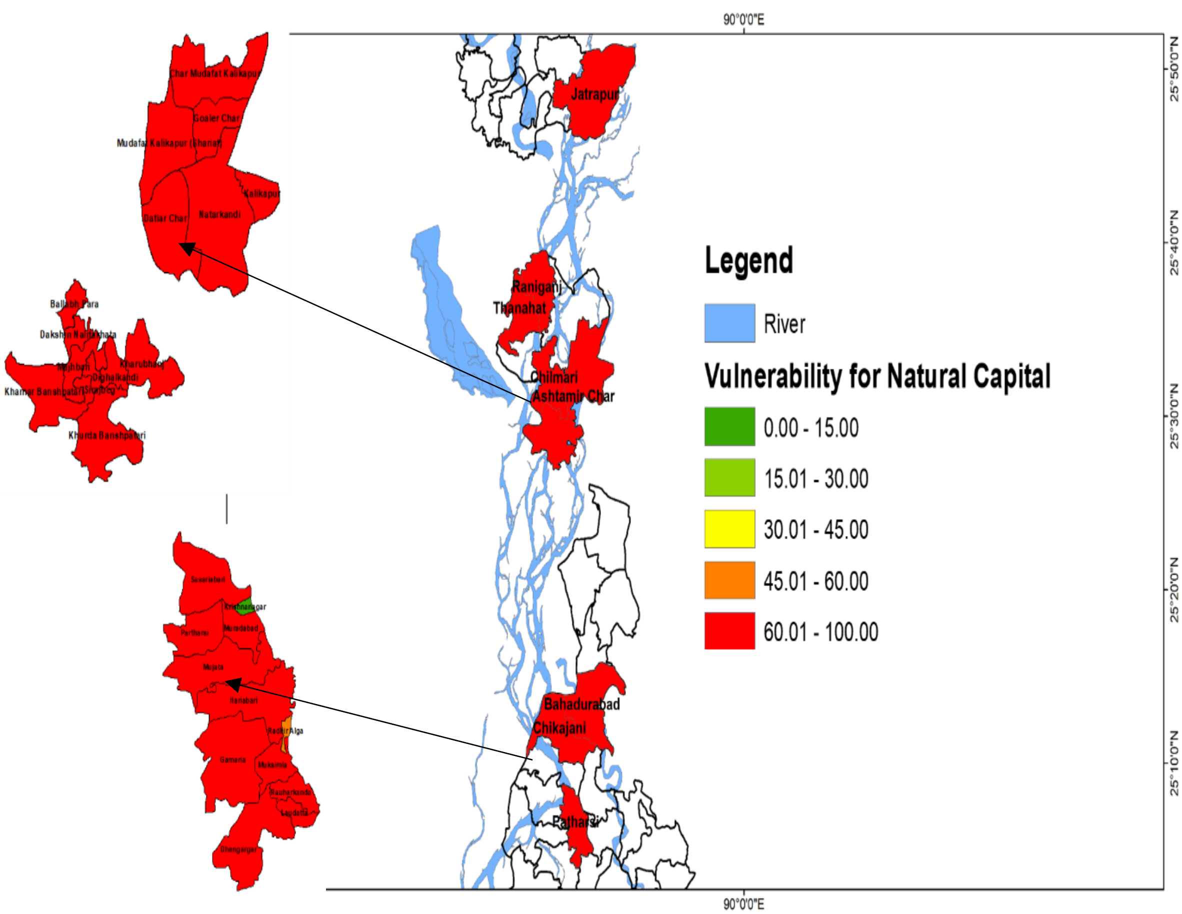

Fig. 10: Natural Vulnerability Mapping of union and village level

Table 5: Percentage of Natural capital and Vulnerability

Natural Capital/ Vulnerability	**Percentage of area (Natural Capital) (%)**	**Percentage of area (Natural Vulnerability) (%)**
Very High	0	100
High	0	0
Moderate	0	0
Low	18	0
Very Low	82	0
Total	100	100

Table 5 shows that the percentage of the area having the lowest capital in the whole study area is the highest and that is about 82% whereas the rest area is covered by low natural capital.

On the other hand, 100% area of the whole study area is highly vulnerable for natural capital. The reason behind this dramatic result is the no of the indicator. This analysis has been used only one indicator that is not desirable. So, it can be said, a different result could be shown if there were more indicators.

Natural Vulnerability at Villages

Among the villages of Ashtamir Char and Patharsi, only Krishnanagar from Patharsi has very low vulnerability with an abundant number of natural capital. And rest of the villages are in highly vulnerable conditions for natural capital.

Financial Capital & Vulnerability

Financial Capital at Unions

Number of HH with access to microcredit, no of Growth Center, Employed People and no. of market/hat are the indicators of measuring financial capital. According to Fig. 11, financial capital at Chilmari, Raniganj and Thanahat unions from Kurigram and Patharsi union from Jamalpur is critically low. Whereas the condition of financial capital at Ashtamir Char union from Kurigram is high. The rest 3 unions have medium to low financial capital.

Financial Capital at Villages

Among the 14 villages of Ashtamir Char, only one village namely Kharubhanj has lower financial capital shown in the above map. Rest villages have fallen in the range of high and very high financial capital’s range. The focus should be given to the specific village (Kharubhanj) in improving financial capital.

On the other hand, all villages of Patharsi union show a mixed distribution of financial capital. The most disappointing village in respect of the financial capital of Patharsi union is Laudatta. Again, Radhir Alga and Muksimla have low and medium financial capital. But the rest of the villages of the union have high to very high financial capital.

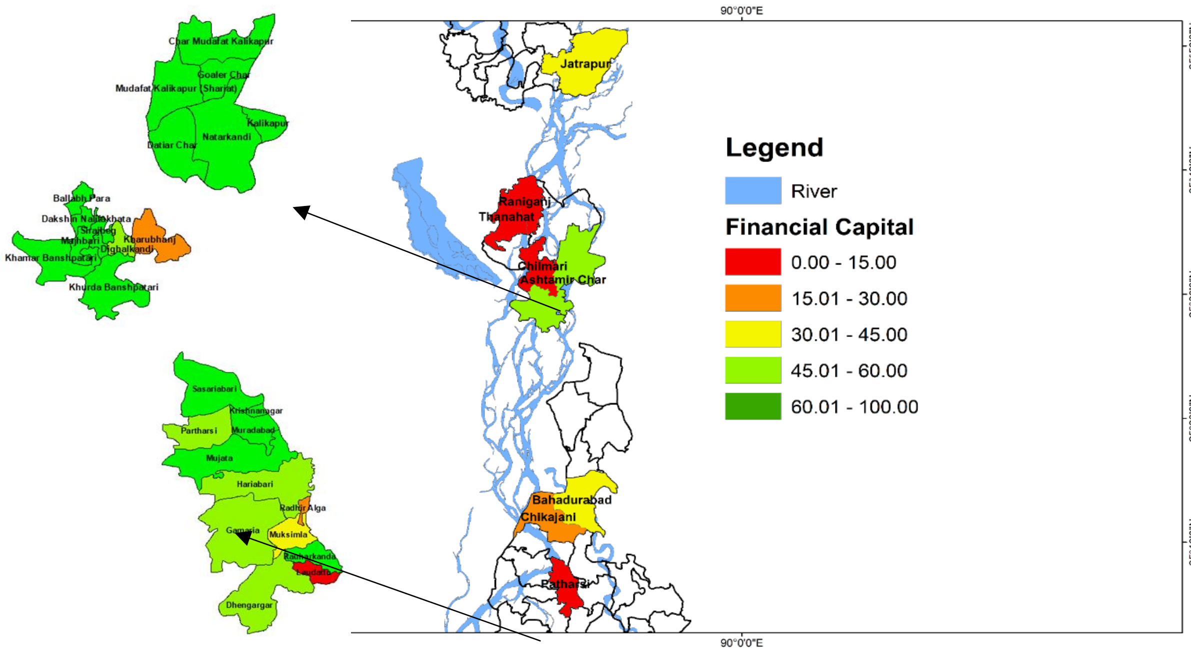

Fig. 11: Financial Capital Mapping of union and village level

Financial Vulnerability at Unions

As the concept of vulnerability is just the opposite of Capital the following Fig. 12 shows the vulnerability for human capital. From the figure below, it is clear that all unions of the study area is high to very high vulnerable to flood due to financial capital.

Table 6 : Percentage of Financial capital and Vulnerability

Financial Capital/ Vulnerability	Percentage of area (Financial Capital) (%)	Percentage of area (Financial Vulnerability) (%)
Very High	0	77
High	23	23
Moderate	35	0
Low	8	0
Very Low	34	0
Total	100	100

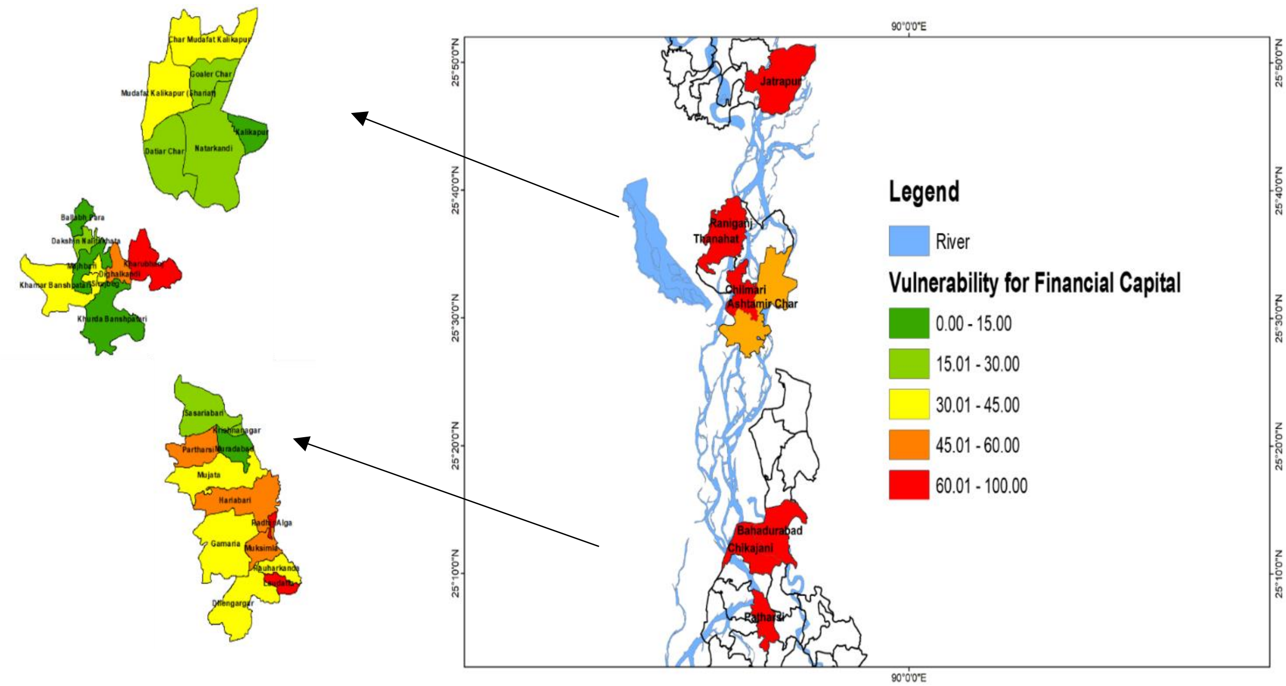

Fig. 12: Financial Vulnerability Mapping of union and village level

The Table 6 shows that the percentage of area having moderate capital in the whole study area is the highest and that is about 35% whereas that of the lowest percentage belongs to very high financial capital. Again, the percentage of area having high financial capital is only 23%. This figure of area percentage shows an unsustainable livelihood condition. On the other hand, the whole study area is highly and very highly vulnerable for financial capital.

Financial Vulnerability at Villages

From Fig. 12 villages of Ashtamir Char, two villages namely Kharubhanj, Dighalkandi is highly vulnerable as these villages have the critical quantity of financial capital. Whereas total 4 villages of the union is under very low vulnerability range and the other 4 villages under a low vulnerability range. Rest villages have fallen in the range of moderate financial vulnerability range. Hence, the focus should be given to the specific villages (Kharubhanj, Dighalkandi) in improving financial capital.

At the same time, Patharsi union shows different results. Laudatta and Radhir Alga villages have the highest vulnerability whereas Mudarabad village has that of the lowest. The rest of the villages of Patharsi have low to very low financial vulnerability.

Total Capital & Vulnerability

Total Capital at Unions

In Fig. 13, the total capital map has been shown. This map has been prepared giving equal weightage to all the capitals. This map will represent the availability of the total capital of the unions and villages.

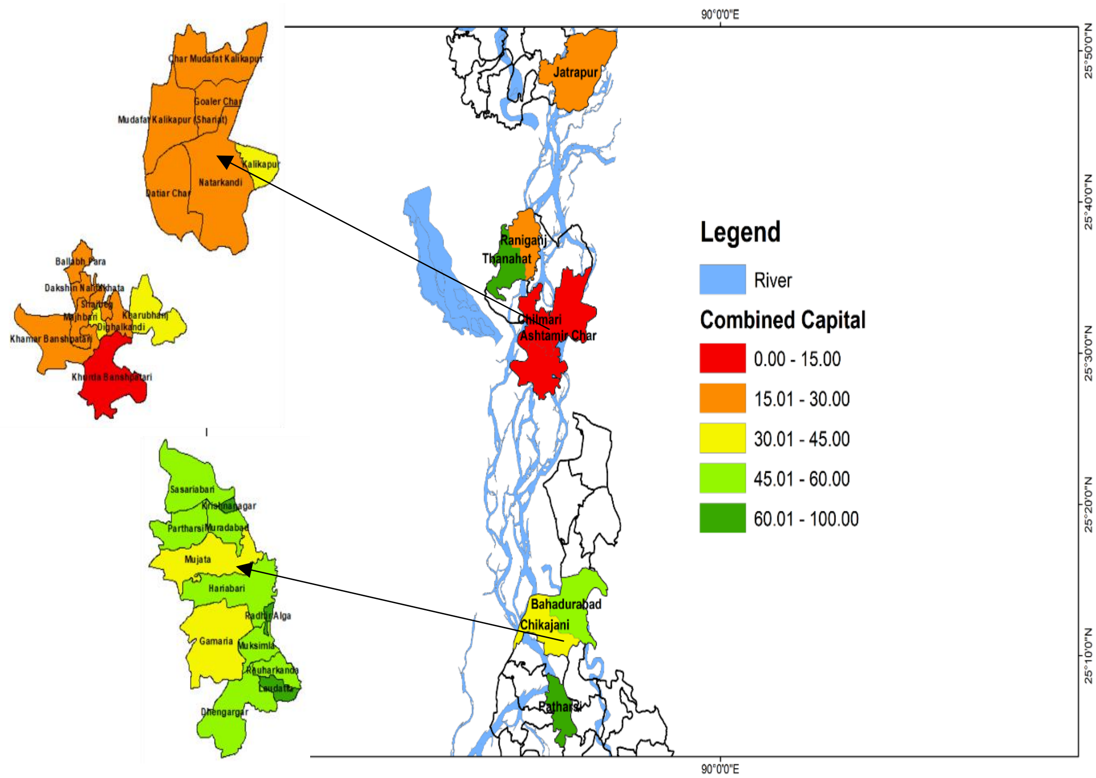

Fig. 13: Total Capital Mapping of union and village level

According to the figure, the combined capital at Chilmari and Ashtamir Char unions from Kurigram is critically low. Whereas Thanahat of Kurigram and Patharsi of Jamalpur have the highest combined capital. However, Jatrapur and Raniganj unions have low combined capital and the rest unions have high to moderate capital levels.

Total Capital at Villages

Among the 14 villages of Ashtamir Char one village namely Khurda Banshpatari has the lowest capital shown in the above map. Rest villages have fallen in the range of moderate to high capital's range. So, this union should be focused in improving capital.

On the other hand, all villages of Patharsi union show that total capital of the villages is very high to moderate. The highest capital found in Krishnangar, Radhir Alga and Laudatta villages in respect of combined capital calculation. Again, Mujata and Gamaria have a medium level of capital. And rest of the villages of the union have high combined capitals.

Vulnerability for Total Capital

Total Vulnerability at Unions

As the concept of vulnerability is just the opposite of Capital, Fig. 14 shows the vulnerability for combined capital. From the figure below, it is clear that all unions of the study area is highly vulnerable to flood due to combined capital except Thanahat and Patharsi. These two unions are very low and moderately vulnerable respectively.

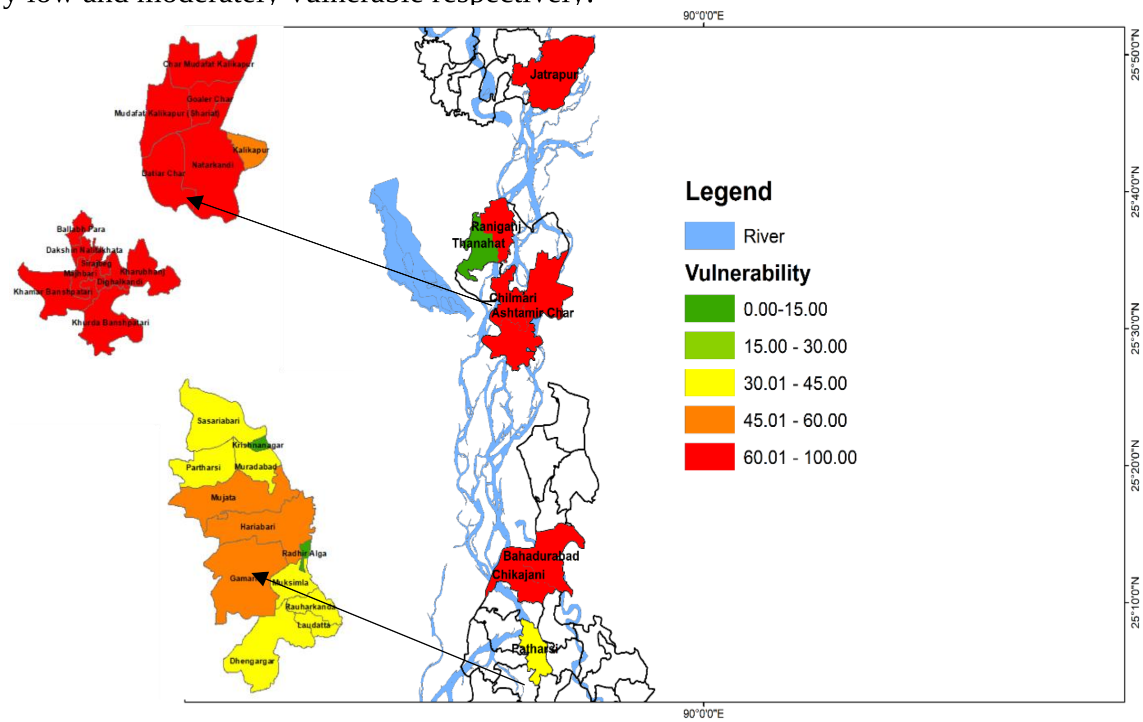

Fig. 14: Combined Vulnerability Mapping of union and village level

The Table 7 shows that the percentage of area having very low capital in the whole study area is highest and that is about 31% whereas that of the lowest percentage belongs to low capital. Again, the percentage of area having high capital is only 13%. This figure of area percentage shows an unsustainable livelihood condition. On the other hand over 80% of the whole study area is highly vulnerable for combined capital and only 10% area has very low vulnerability.

Table 7 : Percentage of Combined capital and Vulnerability

Combined Capital/ Vulnerability	**Percentage of area (combined Capital) (%)**	**Percentage of area (combined Vulnerability) (%)**
Very High	18	82
High	13	0
Moderate	8	10
Low	0	0
Very Low	31	7
Total	100	100

Total Vulnerability at Villages

From 14 villages of Ashtamir Char, all villages are highly vulnerable as these villages have critical quantity capitals. Hence, the focus should be given to the whole union in improving 5 capitals.

On the other hand, Patharsi union shows different results. Krishnanagar and Radhir Alga villages have the lowest vulnerability whereas Mujata, Hariabari and Gamaria villages are highly vulnerable. Rest of the villages of Patharsi have moderate vulnerability due to combined capital.

3.3 Exposure Mapping

The exposure map shows the exposed elements in both union and village level. In this study for exposure mapping, 4 indicators have been selected. These are population density, household size, number of para for villages and number of villages for unions. Again, housing condition is categorized to be an exposure. In the following figure (Fig. 15), the exposure map has been shown. From the above figure, it is clear that all unions except Patharsi of the study area is highly exposed to flood. As the population density of the unions is very high. Again their literacy rate is not that high thus household size is big and also their socioeconomic condition is not improved. All of these are the reason for being highly exposed. On the other hand, the condition of Patharsi is improved hence has lower exposure.

All villages of Ashtamir char are highly exposed to floods. Whereas the condition of Patharsi union is different. Krishnanagar and Radhir Alga villages have the lowest exposure because these villages are very low densified. And Mujata and Gamaria villages have the highest exposure. Rest of the villages have moderate to high exposure.

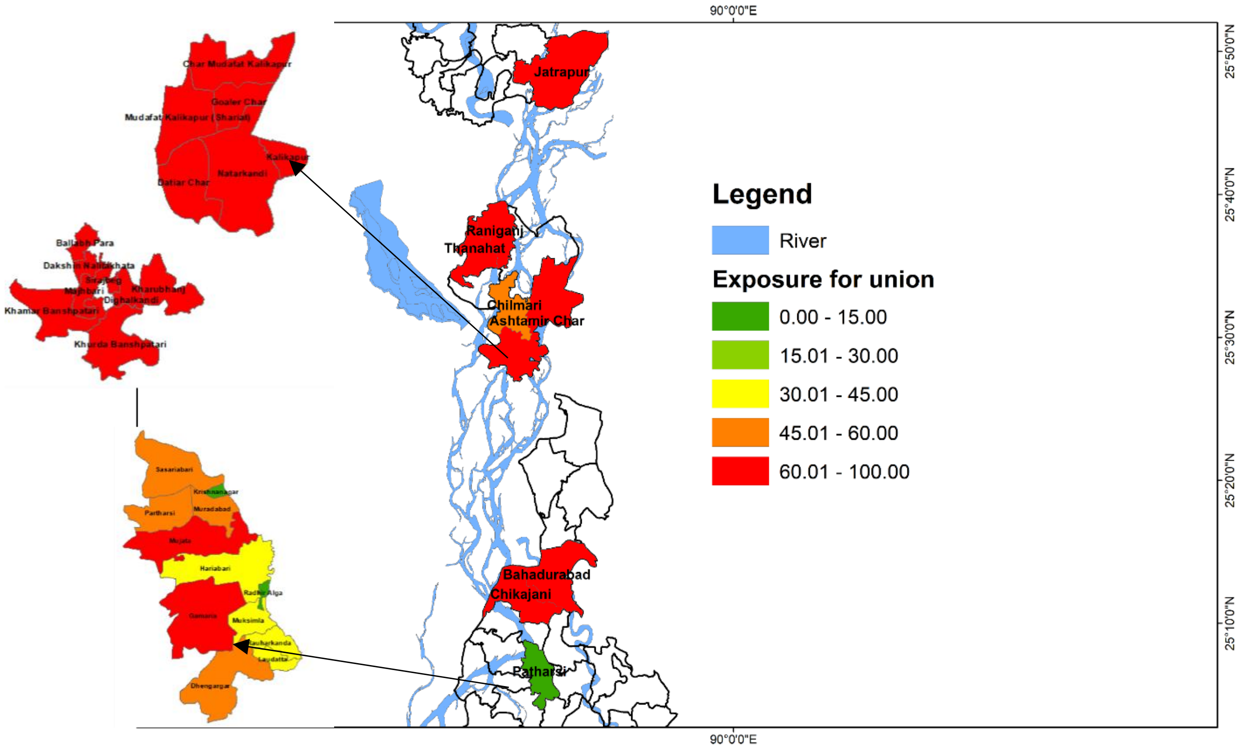

Fig. 15: Exposure Mapping of union and village level

3.4 Risk Mapping

Risk is a function of hazard, exposure, and vulnerability. Again vulnerability is linked to susceptibility and adaptive capacity. Fig. 16 shows the risk map of the study area. Chilmari and Chikajani unions are the highest risk-prone area having highest exposure, vulnerability and lowest capital. On the contrary Jatrapur, Thanahat, Bahadurabad and Patharsi union have the least risk. The rest unions have a moderate risk. The risk at Ashtamir char is moderate. So, the villages of the union have medium to low-risk profiles. However, Patharsi union itself is in a low-risk zone and the villages of the union are also in very low-risk zone.

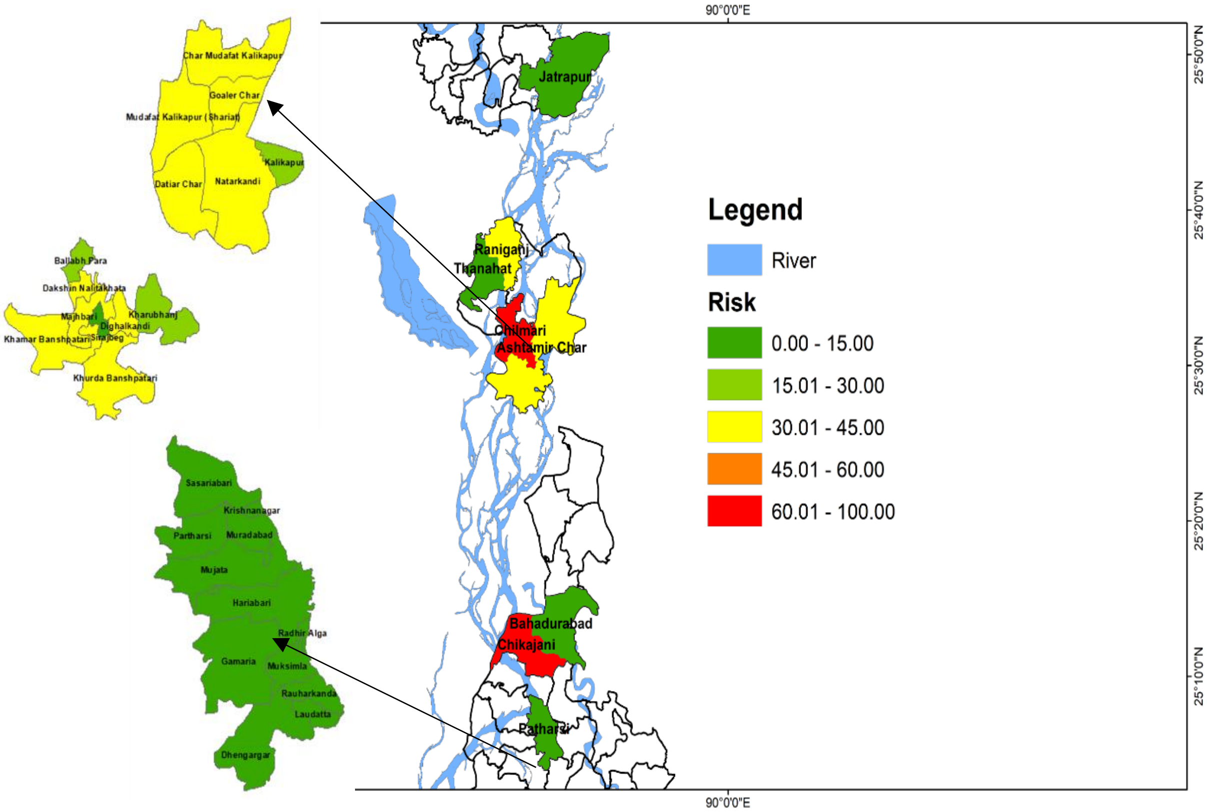

Fig. 16: Risk Mapping of union and village level

4 The current practice of Flood EW and risk communication and the remaining gap

Bangladesh is located downstream of three large river basins: The Ganges, Brahmaputra and Meghna river basins. The total catchment area of these basins is 1.72 million km², with almost 93% of the catchment area situated outside the territories of Bangladesh – in Bhutan, China, India and Nepal. The topography, location and discharge from each of these three basins shape the annual hydrological cycle of the country (HKH-HYCOS project).

Over a year, Bangladesh experiences periods of extreme water availability – too much and too little water. Monsoon precipitation from June to September is the main source of water, and the country has less water available outside of this season, termed the "dry period." Heavy rainfall during the monsoon period is the main cause of flooding; this occurs almost every year, with a devastating flood every 5–8 years (FFWC, 2004). Such flooding causes severe damage to agriculture and infrastructure and the loss of human lives.

Bangladesh has implemented flood control and drainage projects since the 1960s. However, structural measures alone cannot protect the people and infrastructure from floods. Complete flood control in a country like Bangladesh is neither possible nor feasible. With this understanding, Bangladesh started developing flood forecasting and warning systems (non-structural measures) for flood management (Bhuiyan, 2006). The objectives were to enable and persuade people, communities, agencies and organizations to be prepared for floods and take action to increase safety and reduce damage. The goal was to alert people on the eve of a flood event.

Developing flood forecasting services

Bangladesh Water Development Board is responsible for flood management through structural and non-structural measures. It also provides hydrological services in Bangladesh. As part of non-structural measures, the Board has been providing flood forecasting and warning services through its Flood Forecasting and Warning Centre (FFWC), established in 1972. Since then, the development of flood forecasting and warning services has made stepwise progress, which can be divided into three stages.

Initial stage (1972–1988) Initially, 11-gauge points were used for real-time flood monitoring and forecast purposes. In this early phase, gauge-to-gauge statistical correlation and Muskingum–Cunge methods were used for predicting water levels. In 1981, WMO and the United Nations Development Programme provided technical assistance for the computerization of the hydrological database. Computer programs were also developed to carry out operations that had previously been performed manually. During devastating floods in 1987 and 1988, flood forecasts of the major river systems proved to be fairly accurate.

Second stage (1989–1999) After the 1987 and 1988 floods, an initiative was launched to develop a flood forecasting system based on a numerical model. WMO engaged the Danish Hydraulic Institute (DHI) to create a flood forecasting model for Bangladesh. During 1989–1991, the national flood forecasting model was developed using a MIKE 11 modeling system. From 1991, additional deterministic flood forecasting efforts were pursued, resulting in forecast lead times being increased to 48 hours. The number of real-time forecasting stations was increased to 16. From 1995 to 1999, the flood forecasting model was further upgraded to improve its forecast accuracy, under the Bangladesh Flood Action Plan. A geographic information system (GIS) module was added to the flood forecasting model, and the number of stations used to support forecast modeling was increased from 16 to 30.

Bangladesh again experienced severe flooding in 1998, for which the flood forecasting and warning services yielded productive and successful results. An internal analysis of the 1998 flood concluded that flood forecasting and warning services should be extended to all flood-prone areas of the country. Besides, the need for the dissemination of flood information to vulnerable communities became very evident.

Third stage (2000 to date) Many lessons were learned from the 1998 floods. Foremost was that the people of vulnerable communities require flood information with a greater lead time. Further, they wish to know when their homesteads are going to be inundated and for how long. This showed that people were demanding area-specific flood forecasts. Moreover, field-level flood and water-related disaster managers also expressed their eagerness to receive timely flood forecasting information. In this third stage, FFWC received support to improve the accuracy and extend the lead time of flood forecasts, expand the provision of flood forecasting services to all flood-prone areas of the country, improve flood information dissemination at the vulnerable community level and build a sustainable institution.

FFWC efforts focused on improving the forecast lead time. It started to use ensemble precipitation forecasts from the European Centre for Medium-Range Weather Forecasts to provide medium-range flood forecasts. Since 2004, FFWC has provided deterministic flood forecasts to 3 days and medium-range probabilistic forecasts to 10 days. FFWC also started to develop its basin model in 2012.

4.1 Flood forecasting and warning activities in Bangladesh

Flood forecasting and warning activities run from April to October every year in Bangladesh. In this period, the field-level hydrological measurements division works closely with the flood forecasting center to provide observed data. FFWC remains open 24 hours a day, 7 days a week during this period.

Forecast products

- ✓ Daily water level and rainfall situation reports

- ✓ Flood conditions summary (provided both in Bangla and English)
- ✓ Forecast bulletins for 24, 48, 72, 96 and 120 hours
- ✓ Rainfall surface map
- ✓ Flood inundation map
- ✓ Interactive voice response (mobile voice message)
- ✓ Special outlook
- ✓ Press briefing

4.2 Early flood warning dissemination in Kurigram and Jamalpur

There is no doubt that an effective early warning system can save lives and property. Early warning systems can also help disaster preparedness programs to establish measures, such as emergency relief operations and evacuations, in advance. Flood forecasting and warning activities have proven very effective in recent years to combat the damaging effects of flooding in this area. FFWC disseminates flood warning information through media and communication outlets using the Internet, fax, telephone, mobile SMS, etc., and uploads the forecasted information daily on its user-friendly website (www.ffwc.gov.bd).

Moreover, FFWC has also started to disseminate flood warning messages using an interactive voice response system. People receive a short message regarding current flood information about Bangladesh's major rivers by calling 1090. This novel system provides timely information to a variety of different users including government departments, agencies, disaster managers, non-governmental organizations, news, media, local government institutions, and individuals. The two methods chosen were Voice Message Broadcast (VMB) for top-down warning dissemination from national to district and local levels simultaneously and Short Message System (SMS) for bottom-up water level data collection from the local to national level. The available 5-day forecast warning message content was made more localized (union level).

Although the villages of Ashtamirchar and Pathorshi were hit by the floods of 2020, due to the well socio-economic conditions of the people here and much awareness before the floods so they do not accept too many attacks. Most of the people (80%) in the area usually receive early flood warning signals through television. However, in public and private initiatives, local representatives announce the flood to the general communities by announcing the mike. Besides, few local people who are relatively educated (25%) collect early flood warning signals and river water level news through SMS system. In this area, many school and college teachers teach their students before, during, and after the flood what they can do to reduce the damage and easily return to normal life after the flood. In addition to this, they have warned the students about the flood warning and announced the closure of educational institutions, and requested the common people to go to safe shelters. However, there are very few people in this area who understand the flood warning signal by practicing indigenous knowledge. Although there are several reasons for this, according to the local people, the main reason is technological enhancement, electronic media, and globalization as well.

In the recent era, people of both inland and char lands are gradually leading into the dependency of technological instruments and advancement. Nowadays, the main conventional source to get weather forecasting are Mobile Phones, TV and Radio for char land inhabitants (Table 8). The main source of early warning systems in the local area is Television and Radio operated by the government and private sectors. But the early warning information that they get from television news doesn't contain localized forecast and impact information. Moreover, Only Growth center (Such as Hat/Bazar) is the only place where they get access to TV or radio. They also informed that they do not receive any early flood warning formally. The Union Disaster Management Committee (UDMC) is well functioning in its areas, and it meets every three months and calls emergency interim meetings in case of disasters. The union also sets up an emergency operation center during floods to monitor and coordinate activities. The union is also developing disaster response volunteers at the ward level, who could act as good disseminators of flood information. Locally volunteers are also actively working in the Early Warning system. There is no telephone tree (channels) being developed with telephone numbers, though there is a toll-free IVRS to enquire and get information on flood levels and flood forecasts from the national level FFWC. However, the community was not aware of the IVRS. The national structure for warning communication lacks the capacity and resources to reach out to the communities effectively. Again, no specified communication equipment is systematically used for warning communication.

The community believed that, to ensure widespread dissemination of warning information, the community focal points or members of disaster management committees can make arrangements for loudspeakers in crowded places like village markets in the locality. They also emphasized the direct dissemination of forecasts to the community from national and sub-national levels. They believed that direct communication would reduce the lag time in reaching information to them.

Table 8: Dissemination system in the study area

Dissemination System	Percentages
TV	56.8%
Radio	4.8%
Phone	35.6%
None	2.8%

Though People have also a dependency on Indigenous knowledge. Indigenous knowledge can be broadly defined as the knowledge that an indigenous (local) community accumulates over generations of living in a particular environment. Most elderly people have trust in their knowledge practiced by them for years. Frog, Ant, Bird, Cloud, etc. are the natural elements used as to get flood forecasting.

Cloud: Black cloud at the western side of the sky is the symbol of heavy rain and flood.

Frog or Ant or different insects: People believes that if frog or ant or insects climbs up the roof of the house of a tree, there is a possibility of a heavy flood.

Bird: A bird name "Suichora" gives them a signal of the heavy flood. As their perceptions when a flock of birds roams around the char, there is a risk of flood drowning the char.

Like these, there are much more indigenous knowledge believed by people. Though each of the knowledge is effective in some way, effectiveness is not the same. The following Table 9 the percentages of the practiced indigenous knowledge.

Table 9: Effectiveness of different indigenous knowledges in the study area

Indigenous Knowledge	Very High	High	Low	Very Low	Unknown
Cloud	20%	78.4%	1.6%	-	-
Wind	13.2%	84.8%	2%	-	-
Red ant	5.6%	85.2%	8%	.8%	.4%
Frog	20.8%	68.4%	10%	.8%	-
Bird	5.2%	35.2%	58.4%	.4%	.8%
M.Lizard	2.8%	11.2%	51.2%	1.6%	33.2%
Taro	6%	6.4%	11.6%	2.4%	73.6%
EarthWorm	4.8%	10.8%	6.8%	2.4%	75.2%
Proverb	7.2%	8.4%	11.6%	.4%	72.4%

Both of the systems is helping people in an early warning system. Climate change and change in biodiversity and generation gaps make people more dependent on TV and mobile phone in the area.

4.3 Risk communication and gaps and challenges in flood early warning system

The current flood early system relies on hydro-meteorological data from across the country. Data from river gauges and rainfall is collected several times a day, phoned into a central Dhaka office and then manually added to a computer register – a time-consuming process that is vulnerable to error. The existing system is well established and produces reasonable forecasts, but the information provided by the warning stations is too technical for ordinary people to understand. The information of increase and decrease water level against the BWDB monitoring stations cover only major rivers and is related to the rise and fall of water levels of various rivers. This is not the vertical and lateral inundation of specific districts or sub-districts which is valuable at the local level. Indigenous knowledge and information at the local level is always not taken into account and as a result, people in vulnerable locations cannot relate these warnings to their lives and livelihoods.

Dissemination of flood warnings is much less developed and works predominately at the national level. FFWC disseminate forecasting through electronic and print media, but most of the Bangladeshi people are very poor and are living vulnerable life in areas where they do not have access to electronic media. The communication system below the district level is not fully operative. Lack of coordination and insufficient communication between Upazila and union levels about flood warnings causes a greater problem, although they are closer to where floods have their main impact and could benefit from receiving flood warnings. Besides, consequences of changing climate, higher seasonal variability and more frequent extreme meteorological events have made communities more vulnerable.

Good overall progress in disaster management is one of the major achievements, but challenges remain in the implementation of effective early warning systems. For such systems to be effective, four elements must be in place: accurate hazard warning; an assessment of likely risks and impacts associated with the hazard; a timely and understandable communication of the warning; and the capacity to act on the warning, particularly at the local level. Although authorities may be capable of disseminating early warnings, the warning dissemination chain is often not enforced through policy or legislation. In our country difficulties in coordination, such as a lack of clarity about roles and responsibilities across institutions with responsibility for early warning for flood hazard.

Perhaps the key challenge for Bangladesh as well as our study areas is translating warning into concrete local action, even for those with effective capacities for forecasting, detecting and monitoring hazards and suitable technologies for disseminating warnings.

Three main obstacles to undertaking comprehensive risk assessments: limited financial resources; lack of technical capacity; and a lack of harmonization among the instruments, tools and institutions involved. Data-sharing protocols and mechanisms still do not exist, information remains scattered across various departments within the sector and does not provide a complete picture of national losses. Producing reliable loss and impact information remains a challenge, especially after large disasters or in difficult environments.

Lack of Institutional Integration

A Good institutional framework stands out as a prime factor for proper flood management. This includes proper institutional arrangement, organizational structures and a strong legislative framework. Different ministries with local government bodies like Upazila Parishad, union Parishad are involved in river flood and stormwater flooding management in Chilmari Upazila. It is evident in the research that there is hardly any cooperation/coordination exists among these organizations. The rigid institutional framework has hindered the effort for coordination as well as information sharing which often leads to undesirable conflicts among the organizations. Implementation of any development requires coordination among the central and local government bodies. The implementation of plans also depends on the ability to enforce plans in terms of financial and institutional capacity. In general, all these organizations suffer from inadequate manpower, funding and logistics. The existing strength of these organizations is inadequate to cope with the immediate crisis of serious flood.

Lack of Fund

Being a developing country, fund constraints are a common phenomenon for Bangladesh. The implementation of any development plan largely depends on donor funding. Because of lack of funding the flood control project are taking longer time than the estimation. Permanent flood control projects need a huge amount of cost. Flood protecting embankment has been failed because of lack of funding as the construction quality is not up to the mark. In general, the maintenance division of any development works occupies a small percentage of the National Budget. In our economic system financial allocation for maintenance, purpose does not exist. The Ministry of Finance and Planning Commission make financial arrangement only for the implementation of the project work. But subsequent maintenance cost is not allocated for those projects. The proper maintenance and operation of the flood control structures are hindered due to a shortage of funds.

Lack of Participatory Approach

Rigid, inefficient bureaucratic practice, procedure orientation and lack of public participation all these events resist the formation of alternatives to manage floods. A guideline for Participatory Water Resource Management is prepared by WARPO. But it is not in practice. There is limited and in most cases, no participation is evident in planning, policy and decision-making phases. The flood management is driven by top-down decision-making. The flood control measures are planned without the participation of the affected people and other stakeholders. Conventional public participation can be perceived as consultation to improve the project details that the authority has designed them. The existing informal practice of the participatory planning process is not based on principles of participation. Due to lack of participation, the development plans fail to address the people's needs and integrate their demands in the plan. The absence of public involvement in the operation and maintenance of control measures and lack of awareness about their role often pose a problem in the proper management of the flood.

Flood Risk Management Strategies

An integrated approach to flood management means the best mix of structural and non-structural measures. These measures are mostly physical. Though, flood in Chilmari is managed by both measures, integration between them is not noticeable. Flood control measures are emphasized than the non-structural measure.

Mismanagement in Warning System

One of the major problems in the flood management system in Chilmari Upazila is the provision of an equal flood warning system within all the unions of the Upazila. From the analysis, it is found that the char unions are the most flood vulnerable unions in the upazila. But from the field survey it is identified that the people of the union of char unions received no warning about the recent flood while the other three unions of the upazila received warning. The consequence of this mismanagement is very bad. In the char union, people saw their seeds just before a few days of the recent floods. If they received the warning in due time a huge amount of agricultural losses could be reduced. The most surprising fact is that, in Ashtamir Char union, people saw their seeds without getting a warning and the seeds were washed away by floodwater. When the water was removed from the land, they saw their seeds for the second time. And even for the second time, all the seeds were washed away by second time flood water. This has occurred only for the mismanagement by the government bodies.

There is an immediate need to update and improve the Flood EWS so that all elements of the Flood EWS provide useful flood warnings to all potential users.

The following are the key elements of the need's assessment:

- ✓ Scale-down the macro-level forecasts to a locally specific warning signal.
- ✓ Identify and incorporate locally available traditional knowledge and techniques to transform existing early warning prediction and forecasts into easy and understandable language. This will also supplement the modeling errors (if any) and the data and information gaps in the forecasting systems.
- ✓ Develop and/or strengthen user-friendly early warning dissemination plan combining local and national flood forecasting system.
- ✓ Identify the exact type and number of the infrastructural support to enhance the local-level early warning prediction and monitoring as an overall process. This was done previously in the form of installing locally understandable rain/ water gauges and flood markers followed by a formal education and awareness process.

5 Key features of the Dynamic Flood Risk Model (DFRM) including comparative advantages (this will also include the maps)

5.1 Background of DFRM

Dynamic Flood Risk Model (DFRM) is an area-specific flood risk model which generates local flood event data (inundation area, depth, velocity, duration, vulnerability, and risk) using the FFWC forecasted information. This community-based early warning system is aimed to increase awareness among the communities to enhance flood awareness as well as enhance community resilience. Flood risk mapping facilitates the administrators and planners to identify areas vulnerable to flood hazards and to what degree they might be affected, and the capability to respond and recover. Fig. 17 shows the Schematization of Dynamic Flood Risk Model. The background work of DFRM model consists of the following tasks.

- Two-dimensional numerical simulation based on previous scenarios
- Generation of hazard information
- Generation of communities' of capitals, exposure, risk and warning

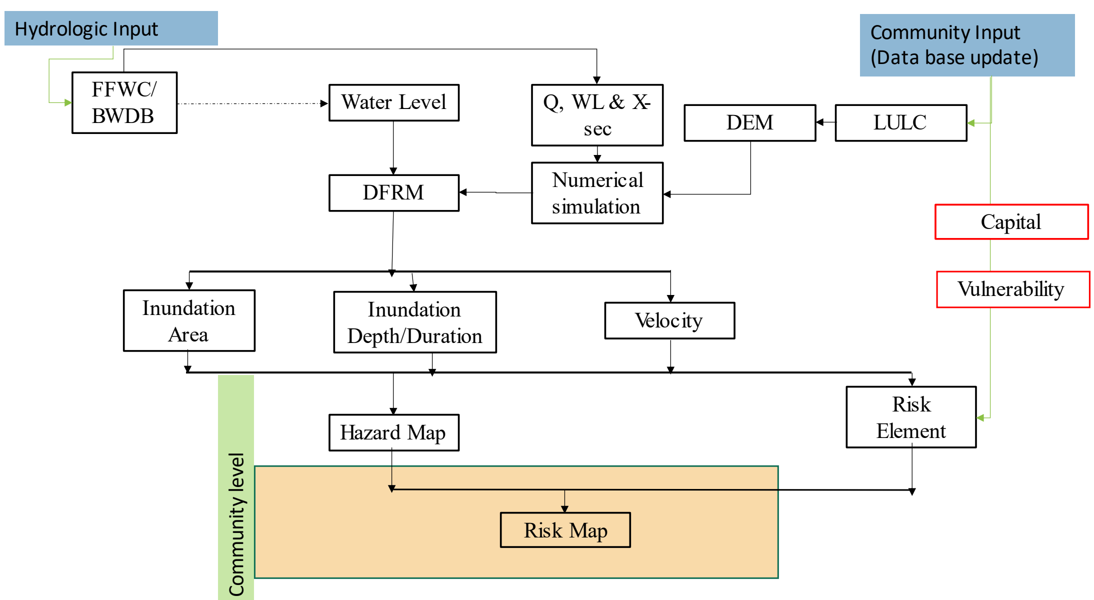

Fig. 17: Schematization of Dynamic Flood Risk Model (DFRM)

The description of each element is given below

Two-dimensional numerical simulation based on previous scenarios

A well-calibrated and validated physics-based nonlinear 2D morpho-dynamic model of Brahmaputra-Jamuna (Shampa et al., 2017) has been used to assess the impacts of several recommended management options. The numerical model was used on the open-source platform of Delft3D (flow version 4.00.01.000000)(Lesser et al. 2004). The Delft3D model has been applied in a wide range of scientific projects for the river, estuarine, and coastal systems (e.g., Van Der Wegen and Roelvink 2008). In the hydrodynamic part, the model solves the two-dimensional depth-averaged shallow water equations (derived from Navier-Stokes equations) for incompressible free surface flow (shallow water equations) with consideration of Boussinesq approximations.

For the numerical model, a 240-km long curvilinear grid was constructed with an average width of 13 km; starting from almost 27 km upstream of the Kurigram district and ending near the Aricha water level measuring station. The reach was discretized by 893x127 grid cells. This grid resolution was chosen to cover every bar by at least two grid cells (grid cell size 450x320 m^2) because the bar size ranges from 549.83x205 m^2 to 28635x10475 m^2 within the reach of Brahmaputra-Jamuna. An example of interpolated river bathymetry for the year 2020 is shown in Fig. 18. As the bathymetry and topography data BWDB measured cross-sections, Digital Elevation Models (DEMs) of SRTM at 1-arc spatial resolution (~30 m), Google Earth DEM and WARPO DEM where is needed.

To simulate any hydrodynamic model the discharge boundary at upstream and water level boundary at downstream is necessary. Therefore from available time-series data (Discharge, Water level) from BWDB nearly 50 scenarios has been generated using the time series data discharge data of Brahmaputra-Jamuna, Teesta, Dharla, Dudhkumar from year 1956-2020 as upstream boundary (shown in Fig. 19-Fig. 22) and water level of Brahmaputra-Jamuana (Aricha), Old Brahmaputra (Jamalpur), Jhenai (Juker char) as downstream boundary (shown in Fig. 23-Fig. 24).

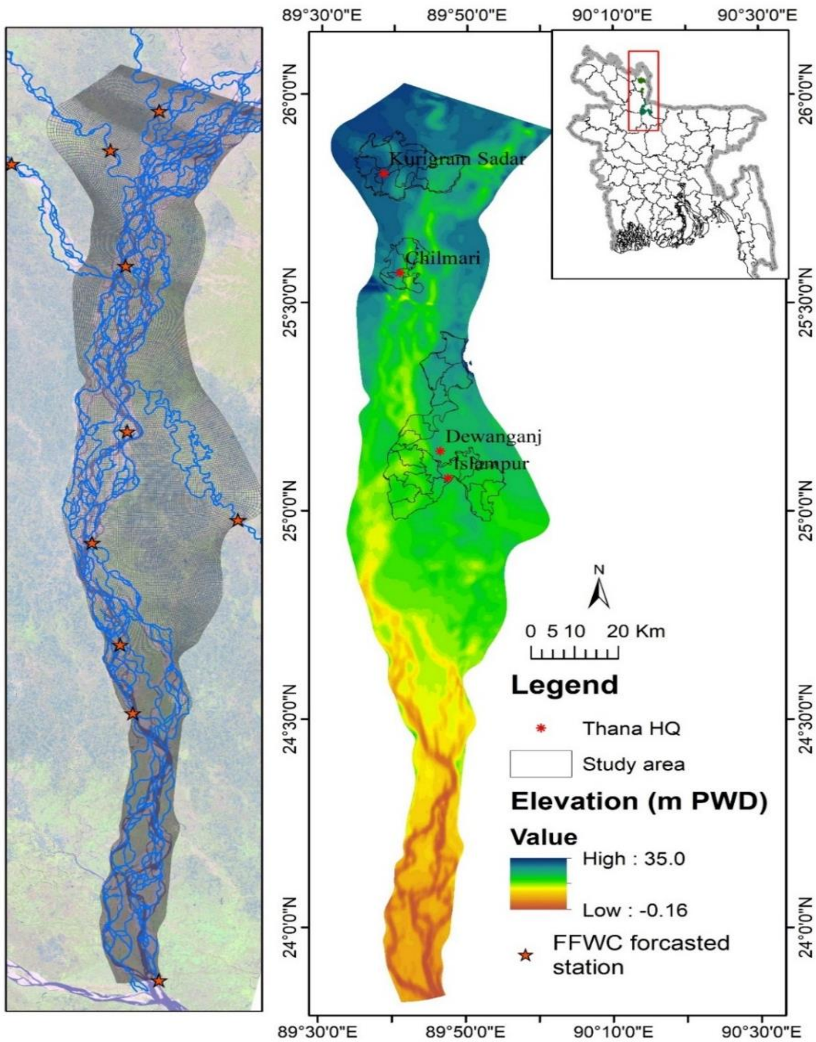

Fig. 18: Model Grid and Bathymetry

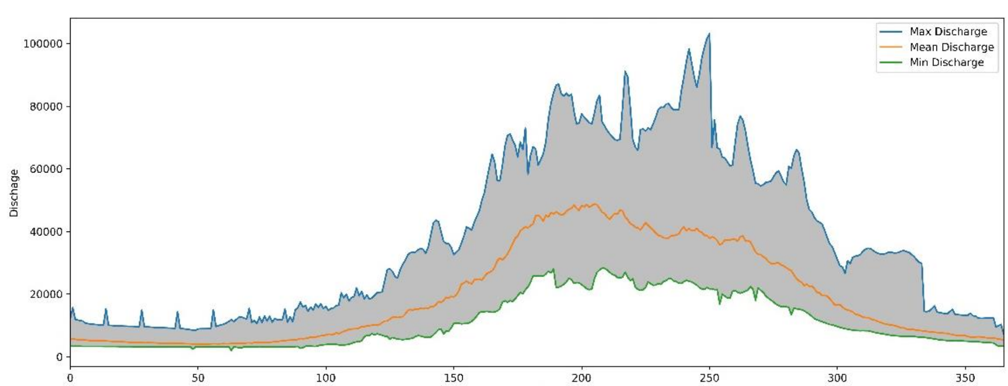

Fig. 19: Discharge range for Brahmaputra-Jamuna river at Bahadurabad (in m^3/s)

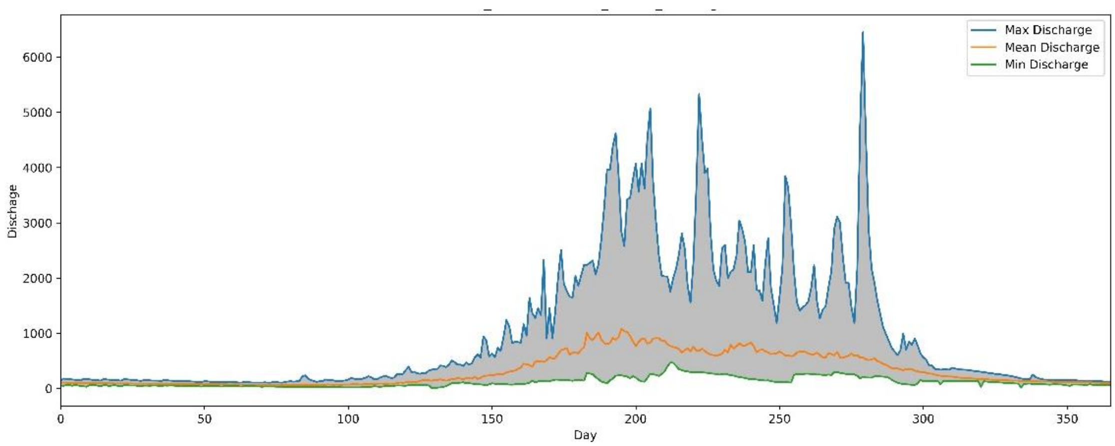

Fig. 20:Discharge range for Dharla river at Simulbari (in m^3/s)

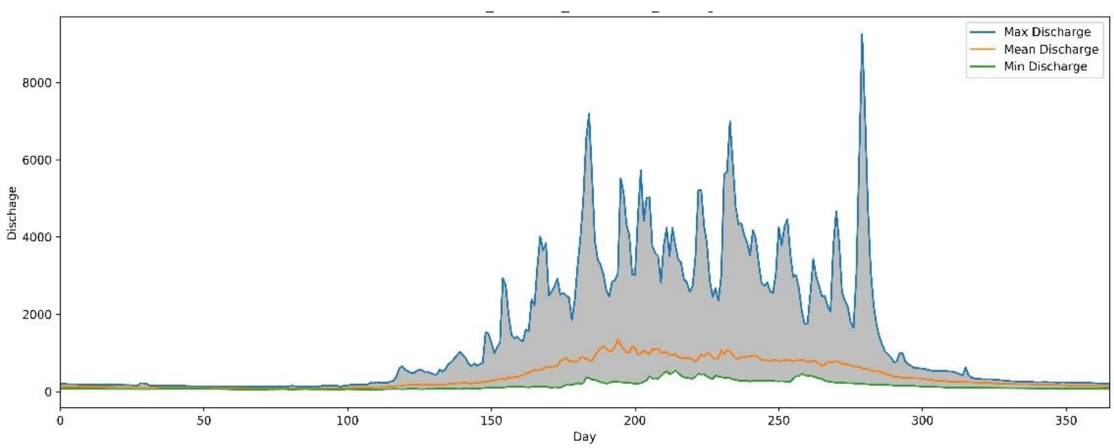

Fig. 21: Discharge range for Dudhkumar river at Pateswari (in m^3/s)

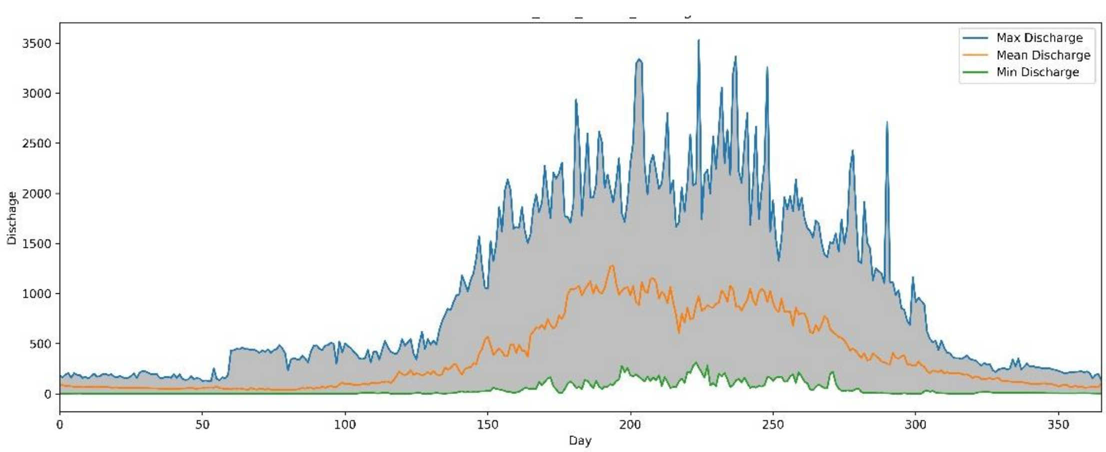

Fig. 22: Discharge range for Tessta river at Dalia (in m^3/s)

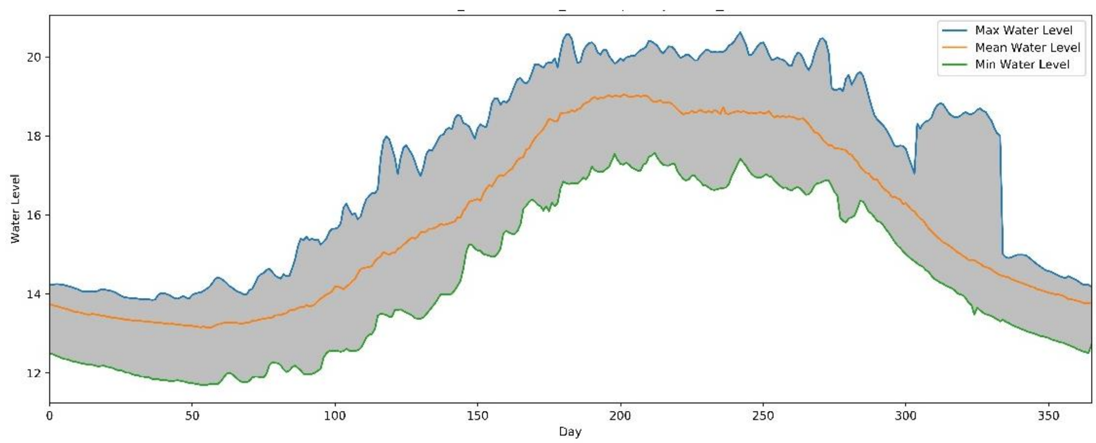

Fig. 23: Water level range for Brahmaputra-Jamuna river at Bahadurabad (in m PWD)

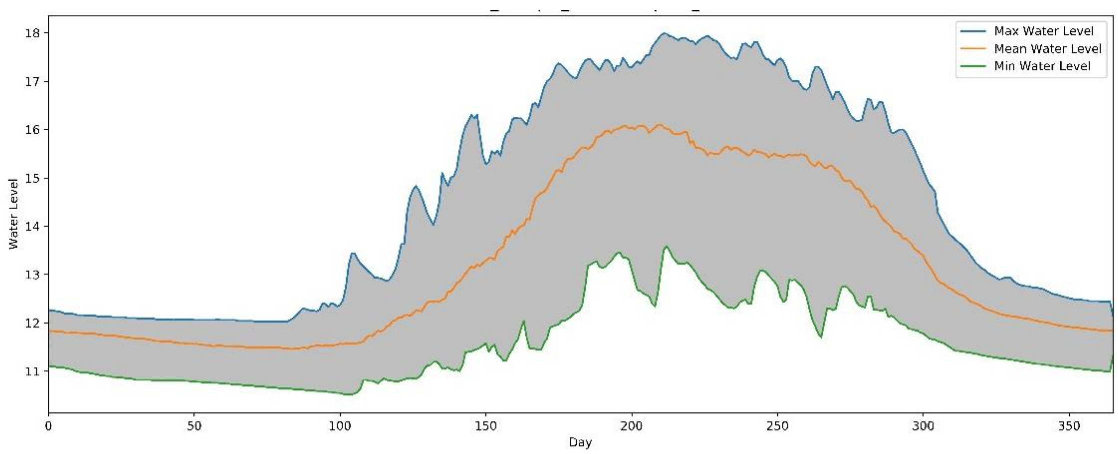

Fig. 24: Water level range for Old Brahmaputra river at Jamalpur (in m PWD)

Generation of hazard information

From the model results components of hazards such as the area of inundation, depth of inundation, duration of inundation and flood flow velocity has been extracted in all scenarios for 365 days. The char people are usually used to flood. The field survey during the study in the chars of Brahmaputra-Jamuna to assess their perception of flood hazards. Hazard ranking 0 indicates a very low hazard corresponding to the inundation is less than 0.1m, overland flood velocity is less than 0.02m with average flood duration (i.e. 60 days for riverine flood). Accordingly hazard 100 indicates a very high hazard with severe damage on life and livelihood corresponds to flooding depth with greater than 1 m, with high velocity and 90% longer duration. Finally, the hazard is calculated using the following formula

Hazard, $H_z = a * W_d + b * W_v + c * W_{du}$…………………………………..(1)

Where,

a, b, c $are\ weighting\ fact$; *Determined by Principal Component Analysis*

W_d, W_v and W_{du} $wighted\ hazard\ index$

The value of a ranges between 0.34 to 0.44, b 0.32 to 0.42 and c 0.22 to 0.24.

Generation of communities' of capitals, exposure, risk and warning

According to IPCC AR5, risk is a multiplicative function (non-linear combination) of hazard, exposure of human and natural systems and vulnerability (IPCC, 2014; Barros et al., 2014) (eq. 2)(shown in Fig. 25) where vulnerability is computed from five various capitals; physical capital, natural capital, human capital, social capital and financial capital (eq. 3). Here, Capitals are calculated from a linear combination (weighted sum) of socio-economic adaptations (UNDP, 2017) shown in Fig. 26 and Hazard component is also computed form the linear combination (weighted sum) of water depth, flood velocity and flood duration The relative weighted scores are calculated by using PCA. PCA gives a correlation matrix that identifies the principal component for a system. Pearson correlation coefficient was used to find the weights of the parameters that describe how much an indicator can explain a component vector**.** Table 1 shows the capitals corresponding to various domains that are used to assess risk.

$$Risk = Hazard * Exposure * Vulnerability \quad \text{.............................(2)}$$

and

$$Vulnerability = 100\% - Capital(in\ percentage) \quad \text{..................... (3)}$$

Risk, Capital and Vulnerability assessed through the following diagrams in Fig. 25 and Fig. 26

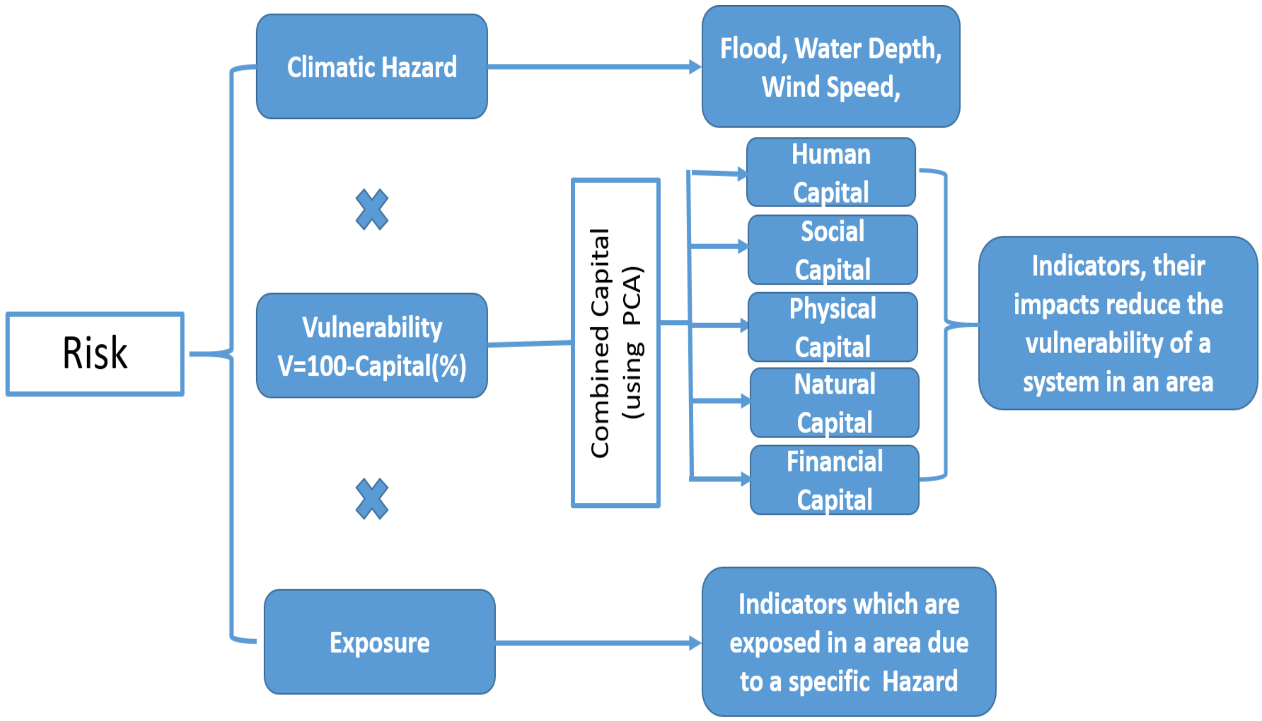

Fig. 25: Risk Assessment

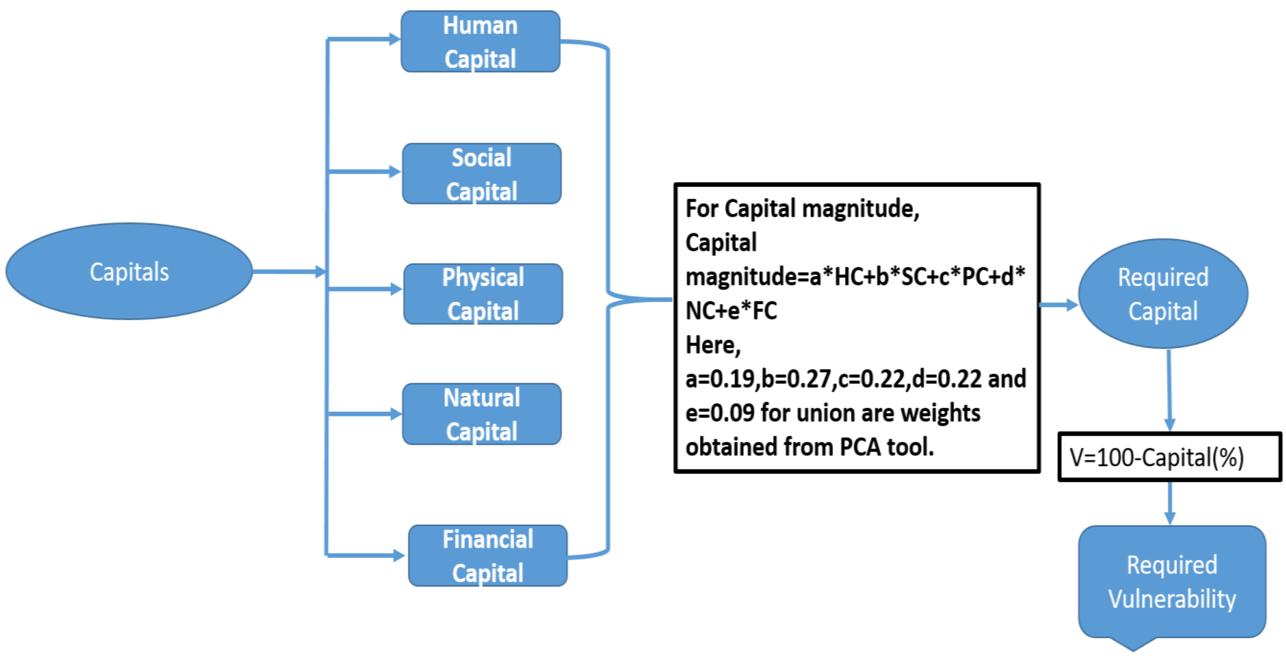

Fig. 26: Capital and Vulnerability assessment

Table 10: Total lists of exposure, hazards and socio-economic capitals.

<table>
<tr><td colspan="2">Domain</td><td>Indicators</td><td>Explanations</td></tr>
<tr><td colspan="2" rowspan="2">Exposure</td><td>Percentage of people living per area</td><td rowspan="2">Exposure refers to the parameters which are directly affected due to any hazard.</td></tr>
<tr><td>Ktacha House in percentage</td></tr>
<tr><td colspan="2" rowspan="3">Hazard</td><td>Water Depth</td><td rowspan="3">Flood is caused by the combined action of fluvial flow from upstream rivers & tide from sea and occurs mainly during monsoon. The main impact zone of the flood is confined within the northern part of the coast which is not protected by polders (Haque and Nicholls, 2018).</td></tr>
<tr><td>Flood Velocity</td></tr>
<tr><td>Flood Duration</td></tr>
<tr><td rowspan="19">Capitals</td><td rowspan="6">Physical Capital</td><td>Educational Institution</td><td rowspan="6">Physical capital comprises the basic infrastructure and producer goods needed to support livelihoods. The infrastructure looks at changes in the environment that affect communication and access to basic services. Production goods are the tools and equipment which increase productivity</td></tr>
<tr><td>Shelter Center</td></tr>
<tr><td>Tubewell</td></tr>
<tr><td>Paka-Semi Paka house</td></tr>
<tr><td>Community Clinic</td></tr>
<tr><td>Religious place (Mosque)</td></tr>
<tr><td rowspan="9">Human Capital</td><td>Cultivable land</td><td rowspan="9">Human capital encompasses the abilities, experience, work skills and good health that, when combined, allow populations to engage with different livelihood strategies and reach their objectives.</td></tr>
<tr><td>Male : Female</td></tr>
<tr><td>Employed people</td></tr>
<tr><td>Access to relief goods</td></tr>
<tr><td>Number of Boat owner</td></tr>
<tr><td>Floating or Hanging Veg Garden</td></tr>
<tr><td>Homestead Plantation</td></tr>
<tr><td>People access to the tube well</td></tr>
<tr><td>Capable People</td></tr>
<tr><td rowspan="4">Social Capital</td><td>Literate People</td><td rowspan="4">Social capital is closely linked with structures and processes for transformation. Structures and processes can themselves be a product of</td></tr>
<tr><td>Involved in Recovery Process</td></tr>
<tr><td>People using electricity</td></tr>
<tr><td>Access to mass media</td></tr>
</table>

		Bazar	social capital. The relationship works in both directions and can be self-perpetuating.
		Moszid going people	
		Number of Volunteer	
		Indigenous knowledge	
		Primary school student	
		Radio station	
		Network Coverage	
	Financial Capital	Number of HH with access to microcredit	Financial capital refers to the financial resources that people use to achieve their livelihood objectives. The definition used here includes flows as well as stocks and it can refer to consumption as well as production. This definition has been adopted to capture an important livelihood building block, namely the availability of cash or equivalent that enables people to adopt different livelihood strategies.
		Insurance	
		Savings	
		Ghat	
		Growth Center	
		Employed People	
		Number of Cattle Owner	
	Natural Capital	Tubewell	Natural capital is the term used to describe the stocks of natural resources from which further resources and services can be developed which may prove useful to livelihoods. A broad variety of resources fall within this category.
		Pond/Deghee	
		Bamboo Bush	

5.2 Key Features of Dynamic Flood Risk Model (DFRM)

Dynamic Flood Risk Model (DFRM) is an easy-to-use software package/tool to identify flood hazard & risk-prone areas that would be useful for decision-makers to make well-informed decisions for flood management. The model interface is shown in Fig. 27. The primary input of DFRM is the water level or danger level information (provided by the BWDB) of Jamuna (at Bahadurabad point), Teesta (at Kauniya point) or Dharla (at Taluk-Simulbari point) river, DFRM generates area-specific Inundation, Hazard, Risk Map as well as Vulnerability and Capacity Map. It also provides area-specific warning from this water level or danger level information. The model also contains community capital, vulnerability and exposure database. A typical example of the vulnerability map of Kurigram and Jamalpur is shown in Fig. 28.

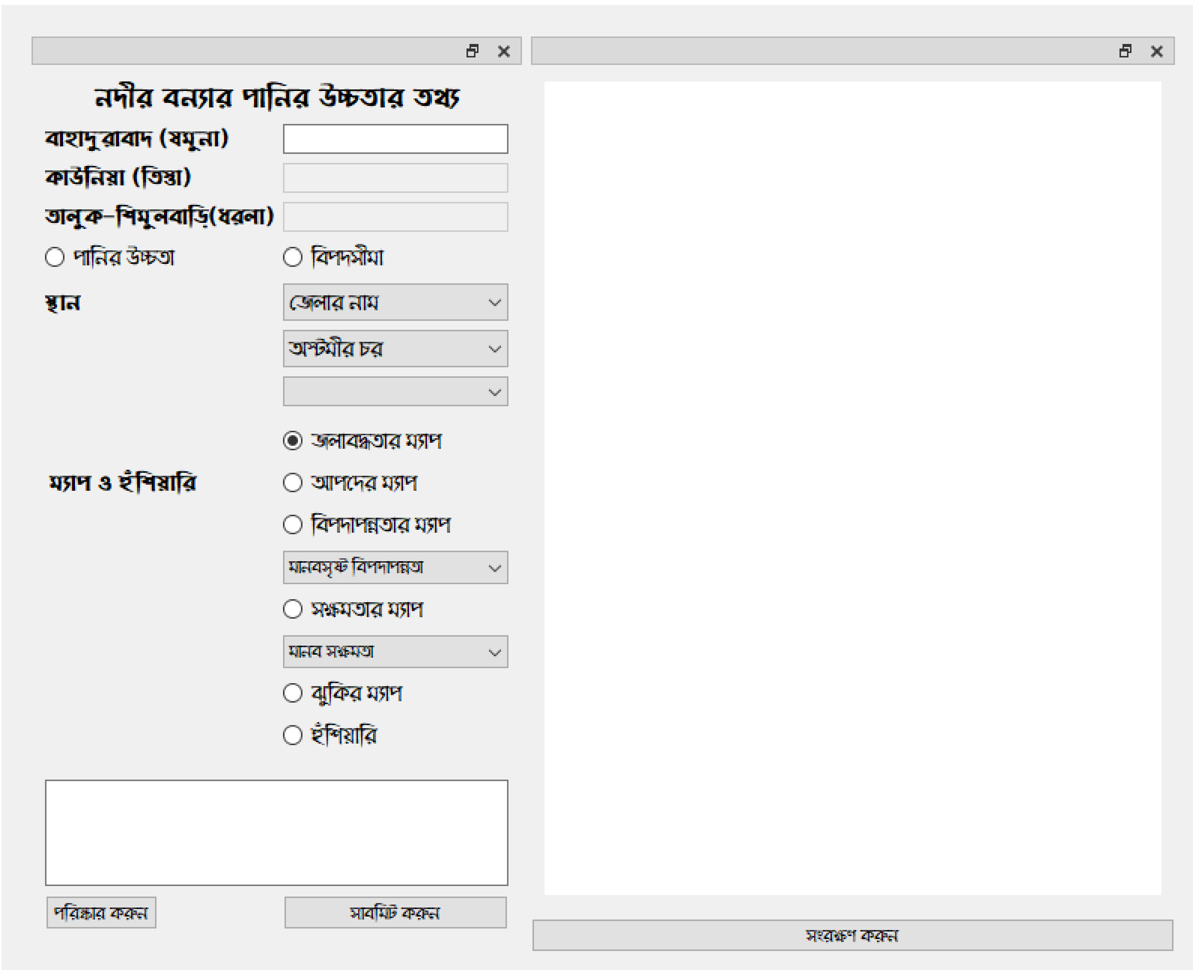

Fig. 27: DFRM interface (Bangla version)

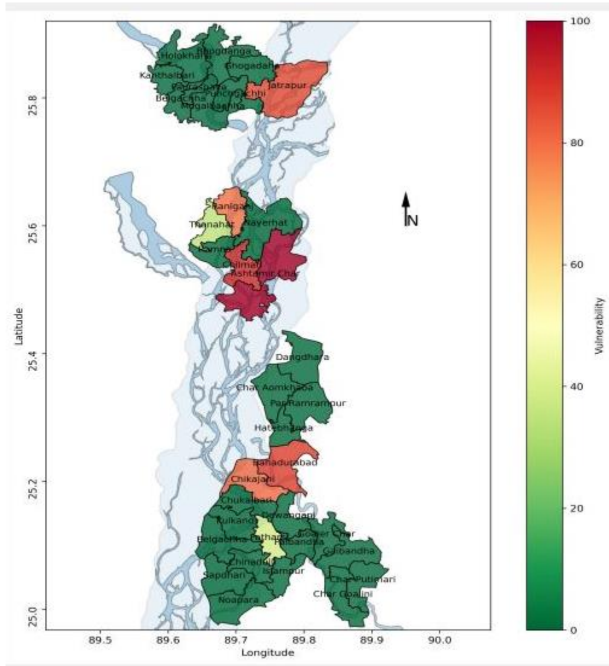

Fig. 28: An example of a Vulnerability map of the study area

Flood risk mapping and warning facilitate the administrators and planners to identify areas vulnerable to flood hazard, people, facilities, and infrastructures at risk and to what degree they might be affected, and the capability to respond and recover. Most importantly, it helps to identify and prioritize the mitigation and response efforts.

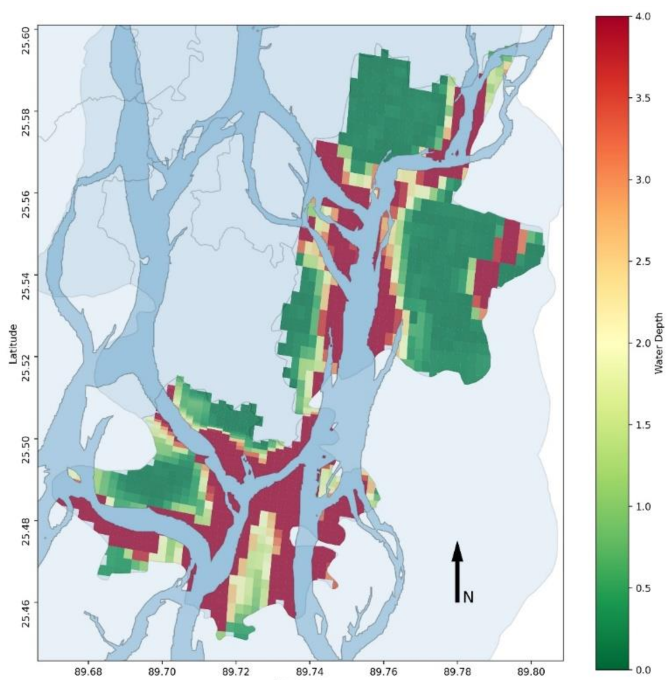

Fig. 29: An example of typical inundation Map at Ashtamir char, Kurigram

Traditionally, flood policies concentrated on the control or reduction of flood hazards, i.e., decreasing the probability of occurrence and intensity of flood discharges and inundations (Fig. 29). Flood risk management puts a much stronger emphasis on flood risk, where risk is defined as damage that occurs or will be exceeded with a certain probability in a certain period. Hence, damage aspects need to be taken into account in any deliberations on flood risk management. Mitigation of flood risk can be accomplished through reducing the intensity of hazards, by engineering or structural measures, which alter the frequency (i.e., the probability) of flood levels in an area, or reducing the exposure or damage susceptibility of the elements at risk, by non-structural measures, for example, through changing or regulating land use, through flood warning and effective emergency response, and flood-resistant construction techniques.

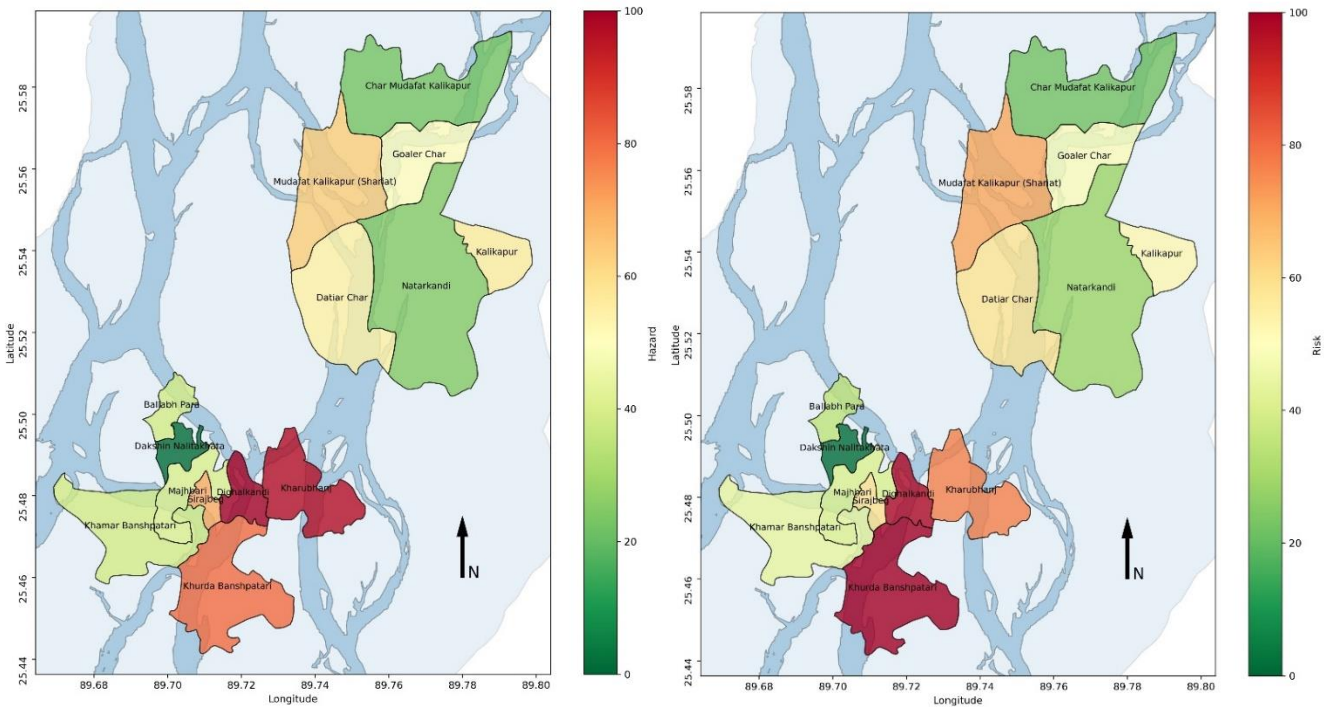

Fig. 30: An example of typical Hazard (left) and Risk (right) produced by DFRM

Identification of those areas at risk of flooding will also help inform emergency responses. For example, areas that are likely to require evacuation can be identified, and evacuation routes can be planned and signposted, so local communities are made aware in advance of an emergency. The identification of flood risk areas will also help in the location of flood shelters for evacuees (Fig. 30). It is essential that specific infrastructure, such as electricity supplies, water supply, etc., and services, such as emergency services, continue to function during a flood event. The creation of flood risk maps will, therefore, allow planners to locate these elements in low-risk areas so that they can continue to serve during an extreme event. In the longer-term, flood hazard and risk maps can support planning and development by identifying high-risk locations and steering development away from these areas. This will help to keep future flood risks down and will also encourage sustainable development.

6 Proposed Institutionalization process of the model

Flood Forecasting and Warning Center (FFWC) of Bangladesh Water Development Board (BWDB) is the focal institution for flood forecasting in Bangladesh which provides daily water level and rainfall situation report with forecast bulletins for 24, 48, 72, 96, and 120 hours from April to October every year. The operational flood forecasting system is based on real-time water level data received from available stations in Bangladesh and quantitative precipitation forecasts from numerical weather prediction models provided by the Bangladesh Meteorological Department (BMD). The forecasted information is national-level information generated in terms of*danger level* 'often difficult to understand by the local community. Furthermore, there is no hazard or risk-related information. The dissemination of FFWC warning goes from National Disaster Management Committee (DMC) to Union DMC with available media coverage. Considering these gaps, the newly developed flood risk information (generated by DFRM) dissemination strategy will follow the existing dissemination process at the same time the community level, under the Union DMC, a new local community unit is proposed (shown in Figure 1.

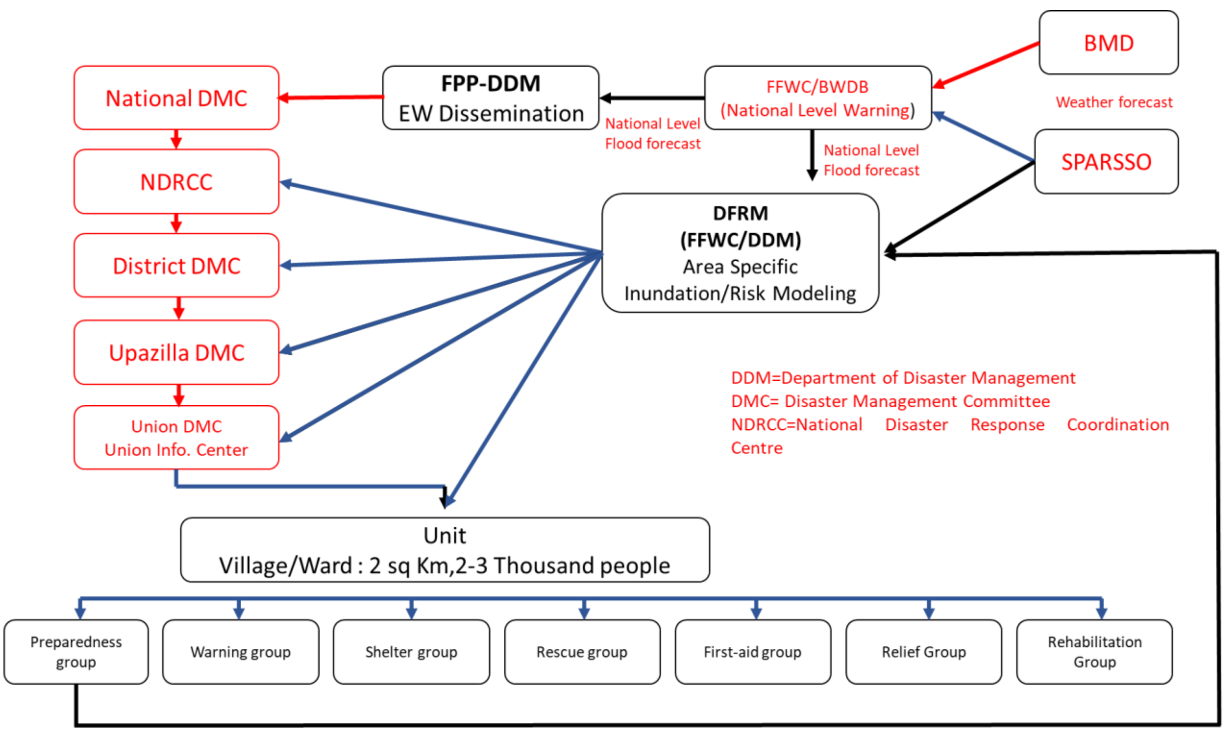

Figure 1*:* Framework on Flood Forecast Dissemination Strategy

For flood warning dissemination NRP:DDM with the partnership of CARE Bangladesh 1440 volunteers are developed in 20 Unions of two 4 upazila in Jamalpur and Kurigrm districts. The unit will consist of several volunteer groups supposed to work into 7 sub-units such as-Preparedness Group, Warning Group, Shelter group, Rescue Group, First aid Group, Relief Group, and Rehabilitation Group. Each group will be formed by three volunteer's one male, one female and one group leader (male/female). The number of volunteers should be sufficient to cover 2 sq. km, providing service to 2-3 thousand people.

6.1 Volunter Development for Flood Preparedness and Response:

In the first between June- July 2020 a total of 864 FPP volunteer developed through training by the NRP:DDM project

District	Upazila	Union	No of volunteer
Kurigram	Chilmari	Chilmari Raniganj Ramna	216 (72 volunteer per Union)
	Sadar	Holokhana Bhogdanga Jatrapur	216 (72 volunteer per Union)
Jamalpur	Islampur	Patharsi Chinadulli Belgachha	216 (72 volunteer per Union)
	Dewanganj	Bahadurabad Chikajani Hativanga	216 (72 volunteer per Union)
Total		**12**	**864**

Picture: FPP Volunteer Orientation & Training Sessions at Jamalpur & Kurigram

On the otherhand during October -November more 576 number of FPP volunteer trained who are ready to provide service on early warning dissemination, preparedness and response. The Union wise distribution of the volunteer as below:

District	Upazila	Union**	No of volunteer
Kurigram	Chilmari	Thanahat Ashtamir Char	144 (72 volunteer per Union)
	Sadar	Mogalbachha Punchgachhi	144 (72 volunteer per Union)
Jamalpur	Dewangonj	Noarpara Sapdhari	144 (72 volunteer per Union)
	Islampur	Char Aomkhaoa Dangdhara	144 (72 volunteer per Union)
Total		**8**	**576**

6.1.1 Capacity Enhancement of the Volunteer

Now, there are 1440 FPP volunteers are in place to render the service amomg the community for reducing the los and damage of flood. After the orientation and training were conducted the volunteers were mobilized and they have participated in the following activities-

- Assisting the UDMC and WDMC to implement their DRR plans related to floods
- Evacuate people to safe place/shelter
- First Aid before, during and after monsoon
- Helping in relief distribution
- Search and Rescue operations

Picture: FPP Volunteers are participating in repairing wooden bridges, relief distribution, evacuation and search & rescue

Project Director, NR:DDM observed the FPP programme at Kurigram and Jamalpur

7 Sustainability

DFRM model is capable of produce the flood hazard and risk information based on the last fifty-year flooding. But the rivers in the study area are very dynamic i.e. the braided nature of Brahmaputra-Jamuna, Dharla and Teesta. Every year during the flooding time the channels and chars experience a massive change. As the channel patterns influence the flooding extent, depth and velocity, therefore it is recommended to consider the variations in DFRM. Moreover, due to climate change, the occurrence of an extreme event like sudden heavy rainfall are increasing which also affect the flood condition of the study area. Hence, the DFRM model is recommended to update once a year. By the course of time, the adaptive capacity of the community will also change, and such information is needed to incorporate in the model timely for precise risk and vulnerability mapping. The community volunteer are found to instrumental for sustaining the mode by effective dissemination of early warning and theby anticipatory action for better preparedness and response for community resileince.

8 Concluding Remarks

This report as well as concept note demonstrates the background work of the Dynamic Flood Risk Model (DFRM) – the two-dimensional numerical simulation, scenario generation and how hazard and risk information has been generated from these modeling works. Though the incorporation of risk information is still on-going.

The concept of the **Dynamic Flood Risk Model (DFRM) under Flood Preparedness Progarmme (FPP)** is formed to disseminate the community-based flood information to enhance community resilience. Therefore, the success of such a technique always depends on the proper dissemination of the information. It is hoped that the information it generates will facilitate the administrators and planners to identify areas vulnerable to flood hazards and to what degree they might be affected, and the capability to respond and recover. At the same time, it will help in the location of flood shelters for evacuees and the longer-term, flood hazard and risk maps can support planning and development by identifying high-risk locations and steering development away from these areas.

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নং- ৫১.০১.০০০০.০৩১.১৪.০২৮.১৭.২১.৬৬ তারিখঃ ১৪ মার্চ ২০২১ খ্রিঃ।

বিষয়: ২০২০-২১ অর্থ বছরের বার্ষিক কর্মসম্পাদন চুক্তির লক্ষ্যমাত্রা অনুযায়ী এনআরপি প্রকল্পের মাধ্যমে "Flood Preparedness Programme (FPP)" এর কনসেপ্ট নোটের মাধ্যমে ডায়নামিক Flood Risk Model প্রণয়ন প্রসঙ্গে।

''ন্যাশনাল রেজিলিয়েন্স প্রোগ্রাম (ডিডিএম পার্ট)'' প্রকল্পের মাধ্যমে ২০২০-২১ অর্থ বছরের বার্ষিক কর্মসম্পাদন চুক্তির লক্ষ্যমাত্রা অনুযায়ী এনআরপি প্রকল্পের মাধ্যমে "Flood Preparedness Programme (FPP)" কার্যক্রমের আওতায় Dynamic Flood Risk Model এর কনসেপ্ট নোট লক্ষ্যমাত্রায় নির্ধারিত সময়সীমার মধ্যে প্রণয়ন করা হয়েছে।

উল্লেখ্য, কনসেপ্ট নোটের সফটকপি ইতোমধ্যে ই-মেইলে প্রেরণ করা হয়েছে। প্রণীত কনসেপ্ট নোটের পরবর্তী প্রয়োজনীয় ব্যবস্থা গ্রহণের অনুরোধসহ এতদসঙ্গে প্রেরণ করা হলো।

সংযুক্তি: "Flood Preparedness Programme (FPP)" এর কনসেপ্ট নোট।

মহাপরিচালক
দুর্যোগ ব্যবস্থাপনা অধিদপ্তর।

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অনুলিপি: সদয় অবগতির জন্য প্রেরণ করা হলো।
১। অতিরিক্ত সচিব ও ন্যাশনাল প্রোগ্রাম কোঅর্ডিনেটর, এন আর পি (ডিডিএম অংশ), বাংলাদেশ সচিবালয়, ঢাকা-১০০০।
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৪। অফিস কপি।