MULTI-HAZARD RISK ANALYSIS
of Climate-Related Disasters in Bangladesh

June 2021

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TECHNICAL SUPPORT

Network for Information, Response And Preparedness Activities on Disaster
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ACKNOWLEDGEMENTS

The report “Multi-Hazard Risk Analysis of Climate-Related Disasters in Bangladesh” has been prepared by the NIRAPAD team for Start Fund Bangladesh under the Start Network UK. The completion of this report would not have been possible without multi-stakeholder engagement and the team wishes to thank all those who have contributed to making this report well informed and comprehensive.

We are grateful for the continuous support provided by the Start Fund Bangladesh secretariat who gave us a clear idea of what was expected, whilst remaining flexible for making additional inclusions that we found appropriate for the study. We are equally thankful to Start Network and Forewarn Bangladesh team for regularly providing constructive feedback and guiding us to ensure the report’s contents are well aligned with the expectations. We have also benefitted from Start Fund Bangladesh members’ participation in the initial DRF workshop that provided us with key insights on the current understanding of the multi-hazard risk, exposure and vulnerability.

We would like to express our sincerest thanks to Bangladesh’s HCTT clusters and working groups who allowed us to present the findings of the study in inter-cluster meetings, and who also remained accessible for providing relevant information as and when required during the study. We have taken into account all the feedback that came during our interactions and incorporated them duly in the report.

Finally, this report heavily relied on the engagement of Kazi Shahidur Rahman, Humanitarian Affairs Specialist, Office of the UN Resident Coordinator, Bangladesh, Jafar Iqbal, Advisor-Climate Adaptation (GIZ) and former NAWG Coordinator, and Asikunnaby, Assistant Professor, Bangladesh University of Professionals (BUP) who have provided the key guidance, information, and analysis support.

The NIRAPAD team hopes this study is relevant for all those working in the humanitarian community of Bangladesh.

ABBREVIATION

BMD	Bangladesh Meteorological Department
CERF	Emergency Response Fund
CHT	Chattogram Hill Tracts
CSO	Civil Society Organization
CSR	Corporate Social Responsibility
DRF	Disaster Risk Financing
ECHO	European Civil Protection and Humanitarian Aid Operations
ECOSOC	Economic and Social Council
EHA	Extended Humanitarian Assistance
FCDO	Foreign Commonwealth and Development Office
FTS	Financial Tracking Service
GFDRR	Global Facility for Disaster Reduction and Recovery
GoB	Government of Bangladesh
HCTT	Humanitarian Coordination Task Team
HRP	Humanitarian Response Plan
INGO	International Non-Government Organization
JICA	Japan International Cooperation Agency
LDCF	Least Developed Countries Fund
LTWG	Localisation Technical Working Group
MoDMR	Ministry of Disaster Management and Relief
NAPA	National Adaptation Programme of Action
NAWG	Needs Assessment Working Group
NGO	Non-government organization
NPDM	National Plans for Disaster Management
OCHA	Office for the Coordination of Humanitarian Affairs
SFB	Start Fund Bangladesh
SFF	Start Financing Facility
SOD	Standing Orders on Disaster
UN	United Nations
UNFCCC	UN Framework Convention on Climate Change
UNICEF	United Nations Children's Emergency Fund
WASH	Water, Sanitation and Hygiene

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EXECUTIVE SUMMARY

Bangladesh is highly vulnerable to recurring hazards and this situation is going to exacerbate due to the impacts of climate change. There is a dearth of data-driven decision-making in the country and typically poverty data is used to guide decisions. This study was an attempt to address that gap by providing data-centric decision-making frameworks using widely accepted global methodologies such as the INFORM index. This study is primarily based on seven years of disaster-related data extending from 2014 to 2020, the major disasters considered were monsoon flood, flash flood, cyclone and storm surge, landslide, and riverbank erosion; however, other hazards were also reviewed such as nor'wester, cold wave, hailstorm, etc. The data sources were NDRCC, DGHS, IDMC, MRVAM, and NIRAPAD hazards reports, etc. The results were verified with long-term datasets such as the EM-DAT. First, data for major disasters were analyzed to understand the pattern of impact, then it helped the multi-hazard risk quantification using INFORM risk index with 24 indicators. Secondly, exposure was quantified up to 2025 using projected data where climate change has been considered. Then, the JIAF severity scale was contextualized, and the severity of needs was calculated using nine indicators. Finally, all the triggers and thresholds of different disasters from numerous sources such as BMD, BWDB, FFWC, GDACS, GloFAS, etc. were analyzed to bring them into a similar pattern for a better understanding accompanied by risk matrices.

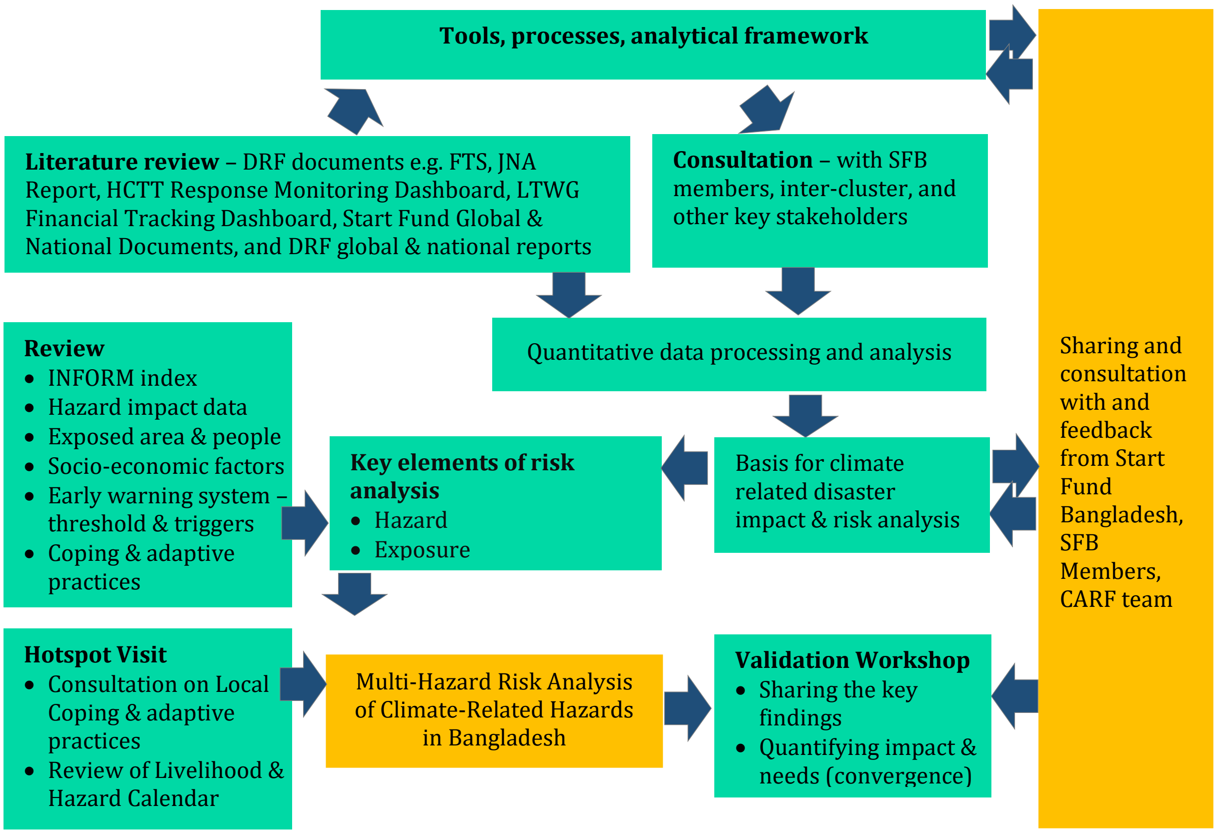
Within the considered period, 15 major disasters affected 42 million people, displaced 9.4 million people, damaged 4.6 million houses either fully or partially, caused 1,053 deaths, and resulted in an economic loss of $4.1 billion. Among the four major disasters, flood (including both Monsoon and Flash flood) affected 34.9 million people- it is the highest and 83% of the total affected 42 million, the next one to have a large impact was cyclone and storm surge which affected 7.05 million people and constitutes 16.78% of the affected population. The results reveal that all districts of the country are exposed to at least one or multiple hazards, however, exposure does not necessarily equate to impact. The multi-hazard risk analysis shows that Kurigram, Gaibandha, Jamalpur, and Sirajganj districts in the north of Bangladesh are at very high risk (>=6.5 out of 10) and high risk (>=5-6.49) districts are mostly spread in the northeast, coastal south and southeast hilly region. The deterministic analysis shows that the impacted population varies significantly ranging from 5 to 778 per 1,000 people. Based on the impact distribution data, an inference can be made with 95% confidence that annually 660 people per 1,000 will be impacted by climate-related hazards from 2021 to 2025. Moreover, annually a total of - 12.10 million people (2.71 million households) could be impacted out of 18.33 million exposed people(4.10 million households) in the next five years considering the multi-hazard risk level. The potentially impacted population was then divided among four severity phases after contextualizing the 2021 JIAF framework to answer questions on where to allocate resources, to whom and when, to how many people, plus on what should be done. Out of 2.71million households, Extreme, Severe, Stress and Minimal class consecutively contains 0.72 million, 0.91 million, 0.63 million and 0.44 million households. In addition, the similar risk matrices generated for the considered hazards based on a detailed literature review of global and local reliable sources is another significant addition to this study.

The findings and frameworks of this study can be used and applied in data-driven decision-making by relevant agencies such as MoDMR, UN agencies, Start Fund Bangladesh, etc. The multi-hazard risk analysis method could be used to identify areas that are likely to be impacted whereas the severity framework could be used to identify the population in need plus these frameworks can be customized for different administrative areas such as the Upazila level. Moreover, this study suggests Household Economy Analysis (HEA), a country-wide sub-national INFORM risk index and climate change integrated hazard modeling to improve future planning and an in-depth evidence-based understanding of hazards, their impacts, and likely needs of the at-risk population of Bangladesh.

1. INTRODUCTION

Bangladesh is considered one of the most vulnerable countries that are likely to face the adverse impacts of climate change (IPCC, 2014; Rahman, 2018). Approximately 80% of the country is floodplain that drains water from big rivers like the Brahmaputra, Padma, and Meghna to the Bay of Bengal in the south- the floodplain communities are highly exposed to frequent hazards and low per capita income only increases their risk (Brouwer et al., 2007). Moreover, evidence of climate change and sea-level rise suggest that coastal communities of Bangladesh are likely to face more frequent cyclones and storm surge events in the future. Recurring disasters in Bangladesh cause loss and damage to life, resources and impede long-term social and economic development. Effective disaster risk financing could assist in addressing these issues and help in data-driven decision making during the onset of catastrophic events. To assist in such evidence-based risk management understanding of disasters likelihood, potential impact assessment and historical trend of impact are necessary. This study focuses on both past and potential future disaster impact (2021-2025), multi-hazard risk, and vulnerability quantification based on seven years of data extending from 2014 to 2020 (Table 2.1), it will then assist in isolating location, validation, and targeting of people in need.

Figure 1.1: Conceptual framework of impact and risk assessment



Detailed reviews were conducted to accumulate data from the Events Database (EM-DAT), National Disaster Coordination Centre (NDRCC), Health Crises Management Centre, Director General Health Services (DGHS), and International Displacement Management Centre (IDMC), NIRAPAD hazard incidence reports. In limitations, this study consists of seven years, and consistent data of loss and damage before that are not available which could have provided greater confidence, a better trend of disaster impact, and assist potential future impact estimates.

2. MAJOR DISASTERS IN BANGLADESH (2014-2020)

2.1. Overview

Bangladesh is at high risk from multiple climate-related hazards. According to the INFORM Risk Index 2021, Bangladesh's risk score is 5.8 out of 10 and it ranks 27th among the 191 countries. In the climate risk index (CRI), generated by Germanwatch, Bangladesh ranks 9th on the list of 10 most affected countries and places 7th on the long term (1998-2017) risk index because of extreme climatic events (Eckstein et al., 2019). Vulnerability for the country lies with its geographic location, where nearly one-fifth of the country is within 1 meter of mean sea level (Huq, 2001). Bangladesh is home to approximately 166 million people within an area of 147570 square kilometres. It is often referred to as nature's laboratory of disasters (Inman, 2009; Rahman, 2018); the name would be justified if one looks at the variety of hazards like- cyclone, storm surge, flood, riverbank erosion, drought, landslide, and salinity intrusion that Bangladesh face every year. Approximately 30% to 70% of the country is flooded each year (Agrawala et al., 2003), the recurring nature of hazards is coupled with a high population density which exacerbates the level of risk exposure. A long-term trend of disasters in Bangladesh based on 120 years (1900-2020) data from EM-DAT data (http://www.emdat.be/) suggests that cyclone and flood are the two most recurrent disasters, they cause huge economic loss and can be associated with some of the significant catastrophic events in the history of Bangladesh, such as 1970 Bhola Cyclone where roughly 500,000 lives were lost.

This assignment looked at the trend of 7 years starting from 2014 up to 2020, there were 15 major disasters (cyclone and storm surge, flood, landslide, and riverbank erosion) where the frequency of disaster completely aligns with the EM-DAT records, meaning these are the disasters that have and will be the cause of damage and loss for Bangladesh. There are 64 districts (level 2 administrative unit) in Bangladesh, within the considered period 58 of them were impacted by major disasters plus many of those faced simultaneous multiple disasters. Even though frequency wise among the 15 disasters cyclone and flood remained almost similar, considering the extent of impact changes the dynamic and flooding has comparatively widespread consequences.

Table 2.1: Yearly impact by major types of disasters (2014-2020)

Year	Affected Population	Displaced Population	Fully Damaged Houses	Partially Damaged Houses	Death	Economic Loss ('000 US$)
2014	3,033,546	357,225	23,314	130,023	59	160,000
2015	5,593,422	696,130	70,523	377,037	84	114,586
2016	5,705,854	529,508	60,920	1,024,372	134	750,000
2017	12,035,016	657,869	140,498	644,478	322	951,000
2019	8,144,460	3,989,081	41,882	568,371	171	144,385
2020	7,509,289	3,192,658	146,740	1,387,506	283	2,000,000
Total	**42,021,587**	**9,422,471**	**483,877**	**4,131,787**	**1,053**	**4,119,971**

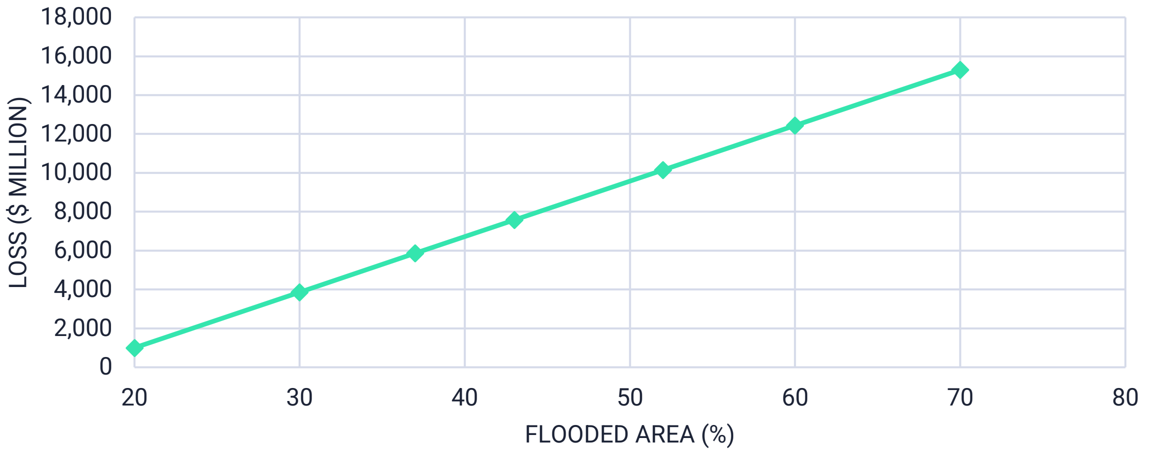
(Source: Emergency Events Database (EM-DAT), National Disaster Coordination Centre (NDRCC), Health Crises Management Centre, Director General Health Services (DGHS), International Displacement Management Centre (IDMC), NIRAPAD Hazard Incidence reports)

Analysis for the considered period reveals that out of a total of 42 million affected people highest number of 12 million were in 2017 where there four major disasters occurred across the country including floods, cyclones, and landslides. Population displacement occurred largely in 2019 (3.9 million) and 2020 (3.1 million) because of three cyclones and two flood events (Table 2.1), it reveals that the high frequency of cyclones and flood impact leads to huge displacement as well. Overall, the disasters for the studied period resulted in 1,053 deaths, 4.6 million houses damaged, and $4.1 billion economic loss.

2.2. Impact of Flood

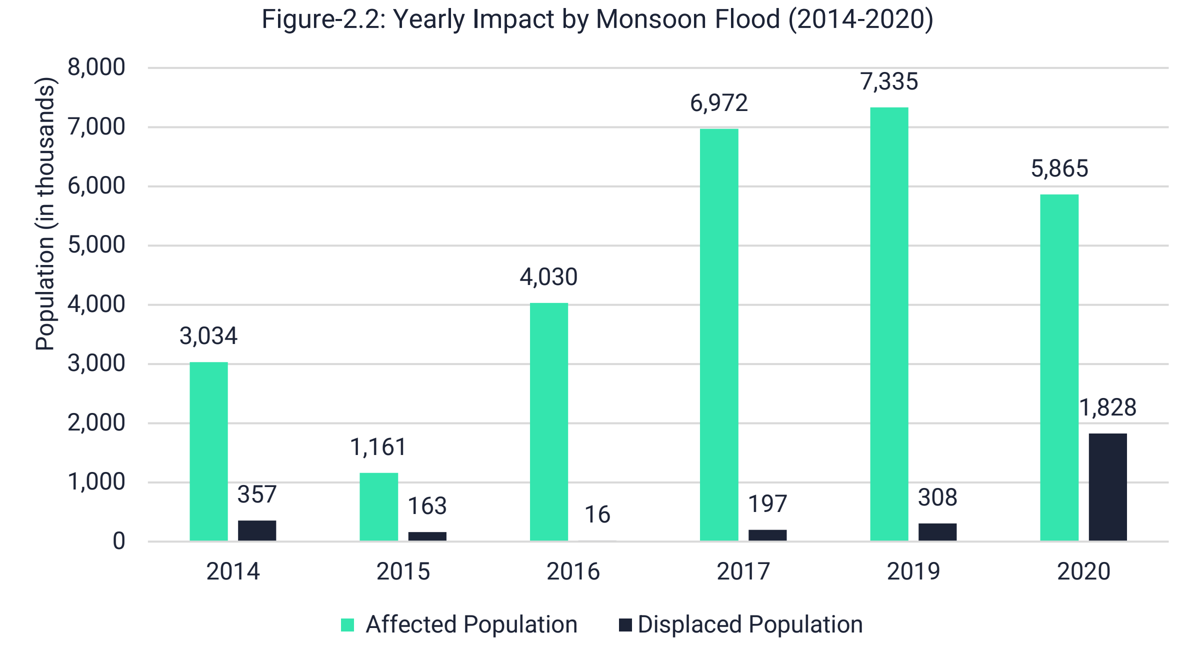
Bangladesh has an extensive flood history that is entwined with the geophysical and social development of the country. The main three rivers (Ganges-Brahmaputra-Meghna) drain a combined catchment of approximately 1,750,000 km^2. The whole of Bangladesh lays within this area and covers almost 8% of the Ganges-Brahmaputra-Meghna (GBM) catchment. The other 92% of the catchment is contained mainly in India but also in Nepal and Bhutan all of which drains out through Bangladesh. The country drains water from a catchment area of about 1.5 million square kilometers which is largely responsible for the numerous well-publicized catastrophic flood events of the 1980s and 1990s.

Figure 2.1: Flooded Area Against Economic Loss Relationship



[Source: ADB Disaster Risk Financing in Bangladesh report 2016 (a 2014 GDP is estimated at $147.3 billion)]

Flooding in Bangladesh normally covers approximately 20% of the land which can increase depending on the scale of the flooding, however, higher return period events (i.e., 100 years) such as the 1988 flood results in a relatively higher amount of flooded area. Data were drawn from the National Water Management Plan on the flooded area and the loss estimate from Asian Development Bank (ADB) report shows a positive linear relationship between flooded area and economic loss (Figure 2.2). For example, some of the extreme flooding events in recent times would include the 1988 flood (60% area flooded) which resulted in total damage to the national economy of approximately $2 billion and it was estimated that 45 million people were directly affected, whereas the direct damage for the 1998 flood (68% area flooded) was $2.8 billion and for 2004 (38% area flooded) it was $2 billion. Although direct relationships can be drawn from these numbers, it requires nuanced understanding and careful interpretation; the percent of the area flooded would not always solely relate with economic losses as there are factors such as longevity of the event, location of the event, depth of floodwater, etc.



(Source: Emergency Events Database (EM-DAT), National Disaster Coordination Centre (NDRCC), Health Crises Management Centre, Director General Health Services (DGHS), International Displacement Management Centre (IDMC), NIRAPAD Hazard Incidence reports)

From 2014 to 2020 there were eight flood events including two flash floods. Monsoon floods caused a significantly higher number of deaths to a total of 705 compared to 19 due to flash floods. Monsoon flood is more frequent, greater in extent, and impacts for a longer period compared to local nature and low frequency of flash flood, this explains the disproportionately high $1.42 billion economic loss, 28.39 million affected people, 2.86 million displaced people and 3.73 million damaged houses by monsoon flood. Flash Flood impacts from 2014-20 are in below table 2.2.

Table 2.2: Yearly impact by flash flood (2014-2020)

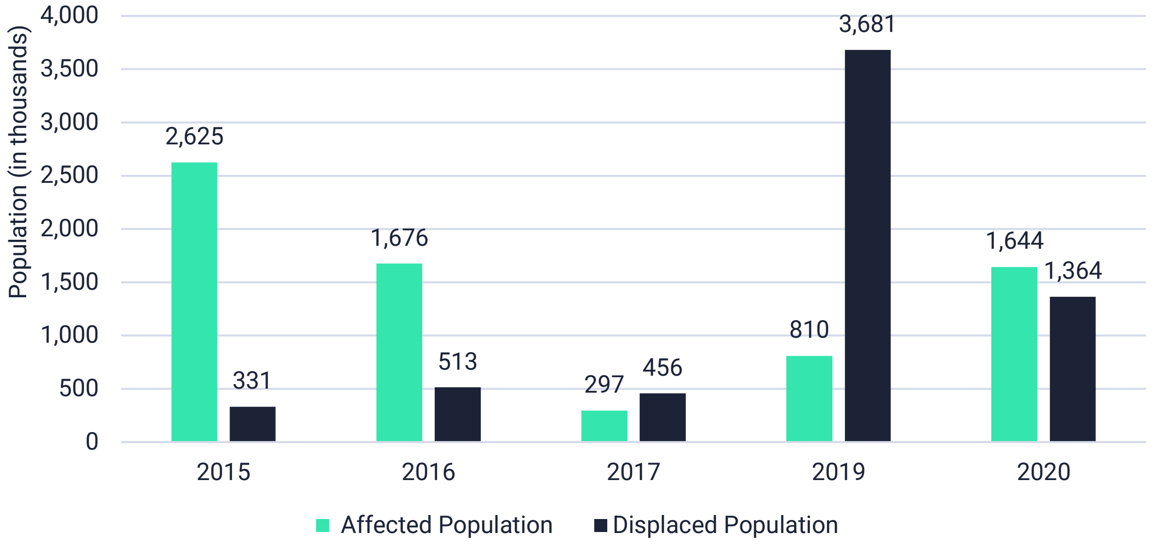
Year	Affected Population	Displaced Population	Fully Damaged Houses	Partially Damaged Houses	Death	Economic Loss ('000 US$)
2015	1,807,335	202,459	27,269	78,090	19	34,586
2017	4,667,623	0	0	28,037	0	128,000
Total	**6,474,958**	**202,459**	**27,269**	**106,127**	**19**	**162,586**

(Sources: Emergency Events Database (EM-DAT), National Disaster Coordination Centre (NDRCC), Health Crises Management Centre, Director General Health Services (DGHS) and International Displacement Management Centre (IDMC), NIRAPAD Hazards reports)

2.3. Impact of Cyclone and Storm Surge

Bangladesh has a prolonged chronicle of frequent cyclonic hazards, which can be partly attributed to its geographic location (the Bay of Bengal in the South) and low (>3 meter from MSL in the coastal region) lying topography. The storm surges are associated with cyclones and they can reach up to nine meter causing loss and damage in Bangladesh during the pre-monsoon (May and June) and post-monsoon (October and November) season. Tropical cyclones occur within 10° and 30° latitudes on either side of the equator, whereas Bangladesh lies in between 20°34' N and 26°38' N latitude with a coastal line of more than 700 kilometers (Islam and Peterson, 2009). Moreover, high population density (1,265 persons/sq.km) and shallow coastal front near the Bay of Bengal exacerbates the exposure to cyclones. Since 1970 cyclone and storm surge in Bangladesh resulted in 363,378 lives lost. Even though deaths have significantly decreased due to developments in early warning, evacuation, and cyclone shelter economic damages are on an increasing trend.

Figure-2.3: Yearly Impact by Cyclone and Storm Surge (2014-2020)

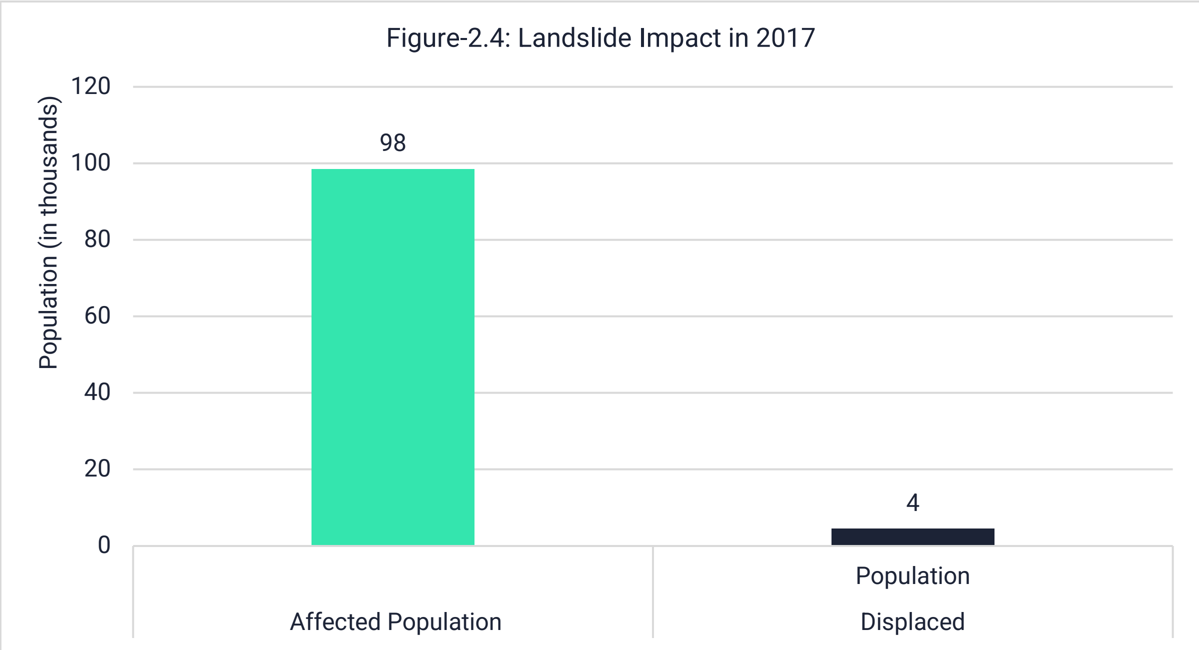


(Source: Emergency Events Database (EM-DAT), National Disaster Coordination Centre (NDRCC), Health Crises Management Centre, Director General Health Services (DGHS), International Displacement Management Centre (IDMC), NIRAPAD Hazard Incidence reports)

Cyclone and storm surge during the considered period caused 158 deaths, $2.3 billion economic loss, affected 7.05 million people, displaced 6.34 million people, and damaged 726,251 houses either fully or partially (Figure 2.1). Cyclone Amphan last year resulted in the highest economic loss of $1.5 billion along with significant death and displacement. Cyclone Komen resulted in 2.6 million affected people, the highest number by a significant margin. The year 2019 experienced cyclone Fani and Bulbul, this is reflected in the highest 52 deaths and displacement of 3.68 million people.

2.4. Impact of Landslide

Landslides have started to become a major hazard especially in hilly areas of the country which make up 18% of the total area of the country. Usually triggered by heavy rainfall, landslides can cause extensive damage to human settlements and activities on the slopes (National Plan for Disaster Management, 2020). The urbanized hilly areas of Chattogram and Chattogram hill tracts are exceptionally vulnerable to landslides having an elevation of 60-150 meter and 600-900 meter above sea level respectively. 83%of landslides are primarily triggered by prolonged rainfall in a short period (Sultana, 2020). Frequent monsoon rainfall within the range of 568 mm to 1404 mm has been seen to be closely associated with landslide occurrences in vulnerable areas (FOREWARN and CARITAS, 2020).

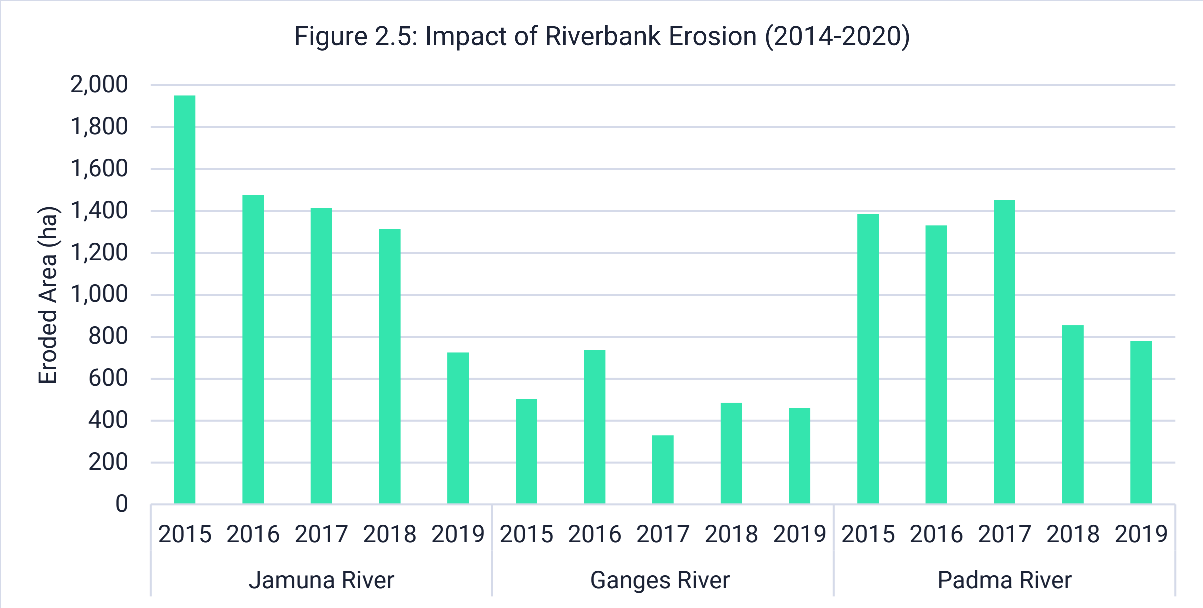


(Source: Emergency Events Database (EM-DAT), National Disaster Coordination Centre (NDRCC), Health Crises Management Centre, Director General Health Services (DGHS), International Displacement Management Centre (IDMC), NIRAPAD Hazard Incidence reports)

Between 2014 and 2020 there has been one major landslide in 2017, which resulted in 171 casualties and that was addressed through the humanitarian response plan. In 2017 landslide cause high $2.23 billion economic loss, 98,491 affected people, 4,484 displaced people and 22,851 damaged houses (Figure 2.4). Earlier reports suggest occurrences of at least 10 other smaller landslides between 1990 and 2012 which together claimed the lives of 404 individuals; however extensive information on damage for these could not be found (Islam, 2018).

2.5. Impact of Riverbank Erosion

Bangladesh's deltaic topography makes the country vulnerable to riverbank erosion forcing people to migrate or resettle. Millions of people have been rendered homeless by this disaster leading to migration in large urban and metropolitan towns and cities where they resort to informal settlements such as slums that lack minimum health and safety standards. The major rivers of Jamuna, the Ganges, the Padma, the Lower Meghna, Arial Khan, and Teesta are highly erosion-prone (National Plan for Disaster Management, 2020). The rate of erosion along the major rivers varies over time and space. It has been observed that the rate of erosion in the Jamuna River was around 5,000 ha per year in the 1980s while in recent years the rate is around 2,000 ha per year. Similarly, the rate of erosion along the Padma River in the 1990s was about 2,300 ha per year, which was about 1,200 ha per year in the first decade of the 2000s (CEGIS, 2019).

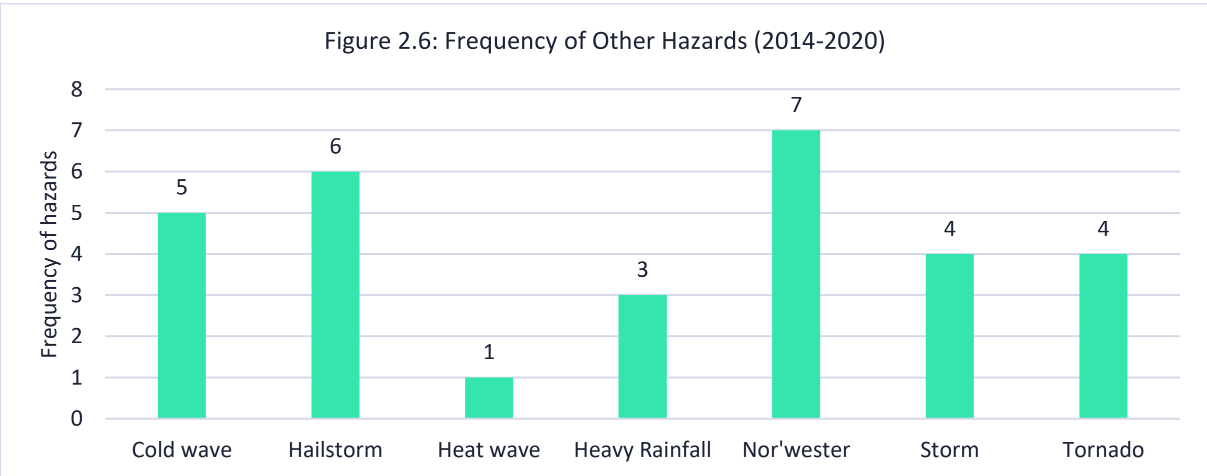


(Source: CEGIS, Riverbank erosion prediction report 2019 & 2020)

Figure 2.5 shows that between 2015 and 2019 around 15,196 hectares of land have been eroded. In 2019, out of 460 ha of land that was eroded, 21 hectares were inhabited by human settlements; moreover, 40 miles of Upazila road and 660 miles of the rural road were also additionally destroyed because of the erosion process (CEGIS, 2020).

2.6. Impact of Other Hazards

Moreover, there are other disasters than the major ones mentioned in the above paragraphs which lead to loss and damage, within the considered period there were 30 disaster events including cold wave, heatwave, hailstorm, heavy rainfall, nor'wester, storm, and tornado. Among these disastrous events, the most frequent ones are nor'wester and cold wave, both also resulted in the highest number of deaths 263 and 194 consecutively.



(Sources: Emergency Events Database (EM-DAT), National Disaster Coordination Centre (NDRCC), Health Crises Management Centre, Director General Health Services (DGHS) and International Displacement Management Centre (IDMC), NIRAPAD Hazards reports)

3. CLIMATE-RELATED CASCADING RISK ANALYSIS (2021-2025)

3.1. Overview

Cascading means passing onto others, here cascading hazards mean amplified effects of events in progression over time, and they generate unexpected secondary events of strong impact. Disaster risk "is the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society, or a community in a specific period, determined probabilistically as a function of hazard, exposure, vulnerability, and capacity" (UNDRR, 2017).

Disasters are the outcome of present conditions of risk (UN, 2015). Risks are geographically concentrated and unevenly distributed (Birkman, 2013). They vary depending on patterns of population distribution and socio-economic development. The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) defines that risk concept has been developed around the central term 'risk'. In this concept, the risk is a result of the interaction of vulnerability, exposure, and hazard (Figure 3.1). The risk analysis involves the exploration of the extreme variability of risk that broadly covers land and population as well as producing maps of relatively high-risk hotspots.

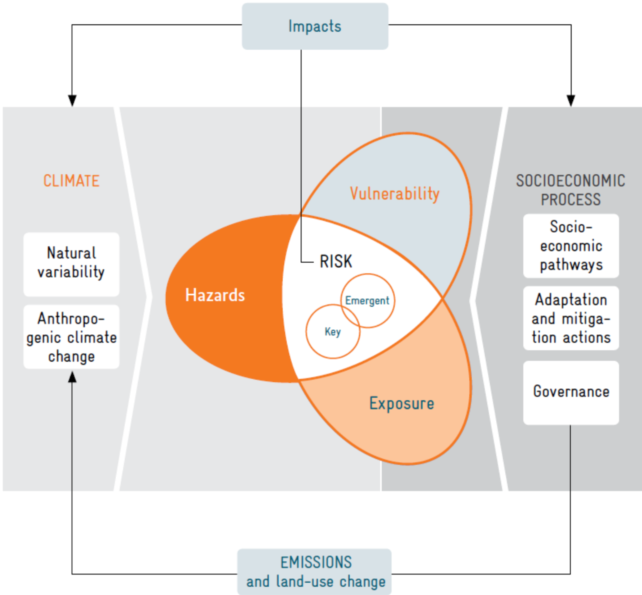


Figure 3.1: The IPCC AR5 risk based conceptual framework. (Source: IPCC AR5, 2014)

Two types of risk assessment have been observed internationally (Birkman, 2013): (1) calculating Disaster Risk Indices (DRIs) for individual hazard types (e.g., for floods or cyclones) or multi-hazard, and identify hotspots of relatively high probabilities of hazard coupled with specific vulnerabilities and lacking in coping capacity and (2) the hotspots approach thus follows a similar model that has been used in the domain of biodiversity. It focuses on the analysis of geographical level in detail. It is also employing data that indicate relatively high levels of the likelihood for hazards as well as combined with geographic information on exposure and vulnerabilities.

Modern analysis of disaster risk incorporates both disaster hotspots and risk indices through geographically disaggregated statistics using hazard profiles integrated with geographical information system (GIS). The resulting maps show relative degrees of risk across the geographic area. This report assesses the climate-related multi-hazard risk consisting of hazards, exposure, and vulnerability with their cumulative indicators to understand and measure the risk.

Using the Global INFORM method, the climate-related multi-hazard risk index is produced for this study combining 24 indicators grouped into three dimensions of risk- hazard and exposure, vulnerability, and lack of coping capacity (see Figure 3.2). The overall risk score ranges from 0 to 10 for each district, dimension, and component of risk. The multiplication of the values of an individual district based on each indicator developed the climate-related multi-hazard risk index of each district which has been qualitatively expressed in very high (>=6.5), high (>=5-6.49), medium (>=3.5-4.99), low (>=2-3.49), and very low (<2) classes.

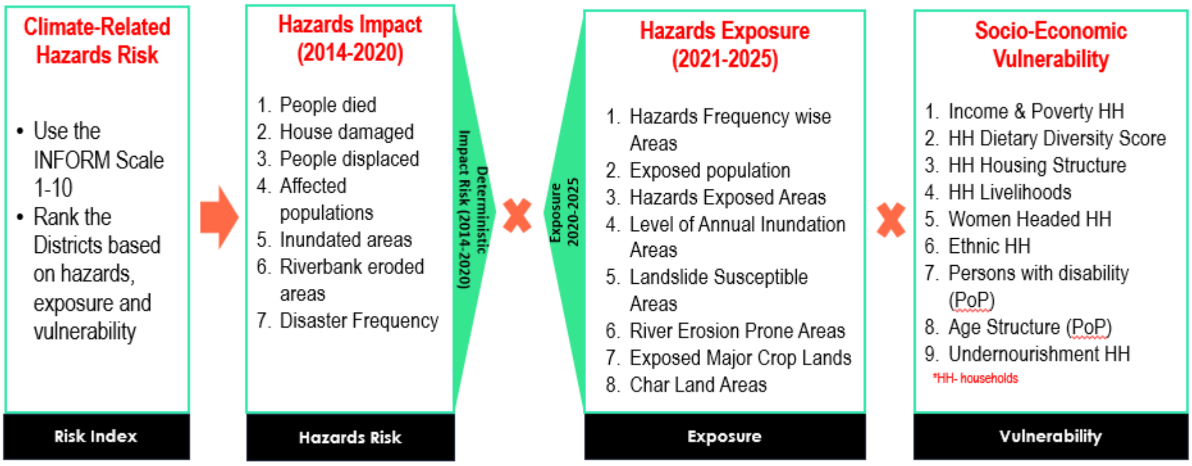


Figure 3.2: Climate-related hazard risk components and indicators

3.2. Hazards Risk

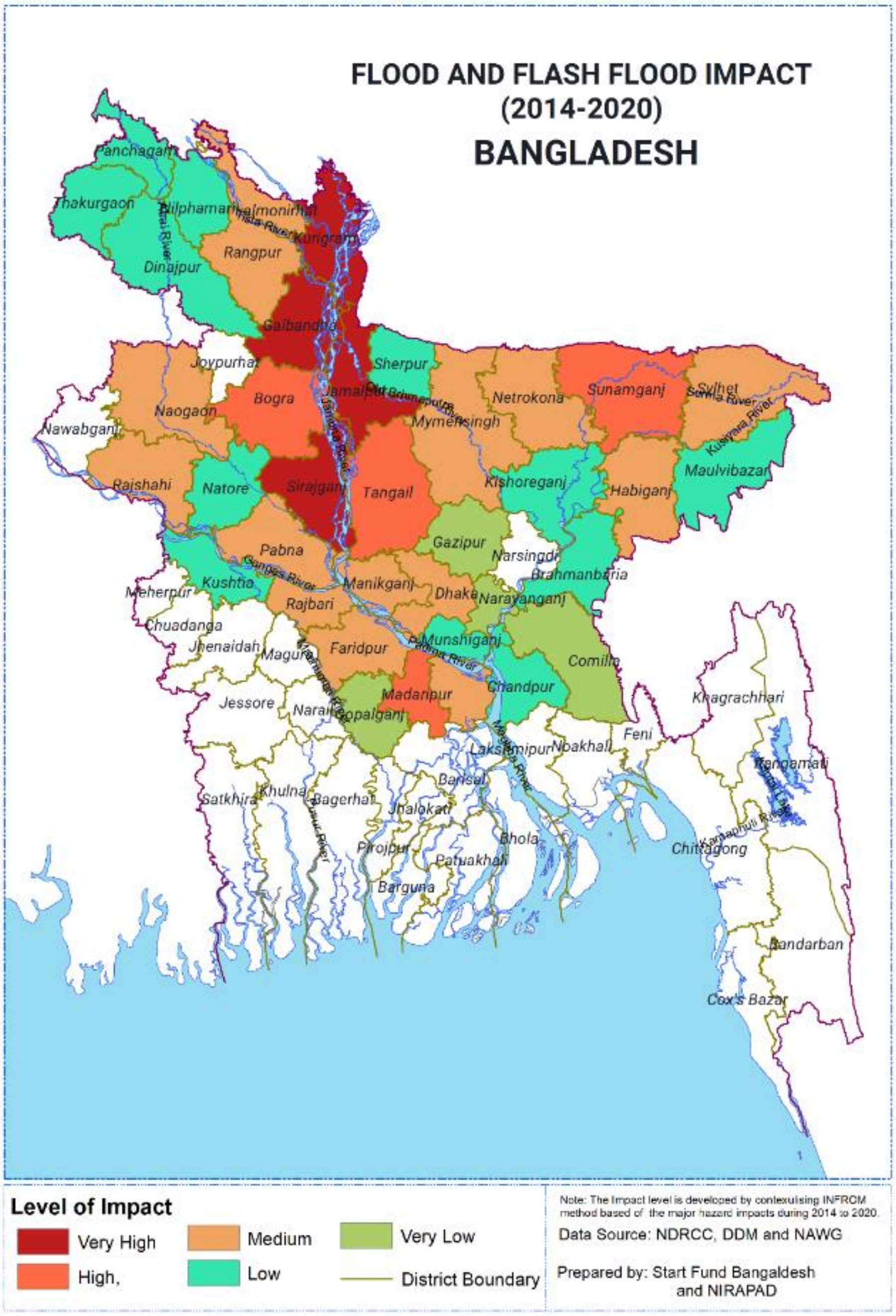
Hazard is defined as “a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation” (UNGA, 2016, 2017). In the IPCC report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.’ According to the World Meteorological Organization (2017), the climate is “the synthesis of weather conditions in a given area, characterized by long-term statistics of the metrological elements in that area. The IPCC has indicated a strong likelihood that climate change will increase the frequency and severity of related hazards and reduce the overall predictability of such hazards based on historical records. For climate-related hazard mapping, many variables can be relevant, for example, meteorological and geographic information for a country or region of a country are usually available from disaster management-related official sources.

Deterministic risk models are used to assess the impacts (loss and damage) of specific hazards events. Typical scenarios for a deterministic analysis include examining past historical events, worst-case scenarios, or possible events that reoccur at different times. For climate-related multi-hazard risk in this study, the deterministic risk model used indicators regarding past (2014-2020) hazards impact (cyclone and storm surge, flood, riverbank erosion, and landslide). For climate-related hazard risk, use seven indicators- 1. number of people died, 2. number of house damaged (partial and full), 3. number of people displaced, 4. number of people affected, 5. inundated areas (flood and cyclone/storm), 6. riverbank eroded areas 7. frequency of disasters.

All the data are compiled from the EM-DAT database, UNOSAT and NASA NRT, National Disaster Response Coordination Centre (NDRCC), Department of Disaster Management (DDM) reports, Centre for Environment and Geographical Information Services (CEGIS) erosion prediction for riverbank erosion reports, and Joint Needs Assessment (JNA) reports (click here to see the full dataset). In Bangladesh among the 64 districts, 58 were impacted by climate-related disasters in the last seven years (from 2014-2020). Total 17 districts (26.25%) were impacted by cyclone, 38 districts (59.38%) were impacted by monsoon floods- among them six districts experienced flash floods at the same time, five5 districts (7.81%) were impacted by a landslide- among them three overlapped with cyclone, 17 districts (26.56 percentage) were impacted by riverbank erosion- among them 16overlapped with monsoon floods.

3.2.1. Monsoon Floods and Flash Floods Risk

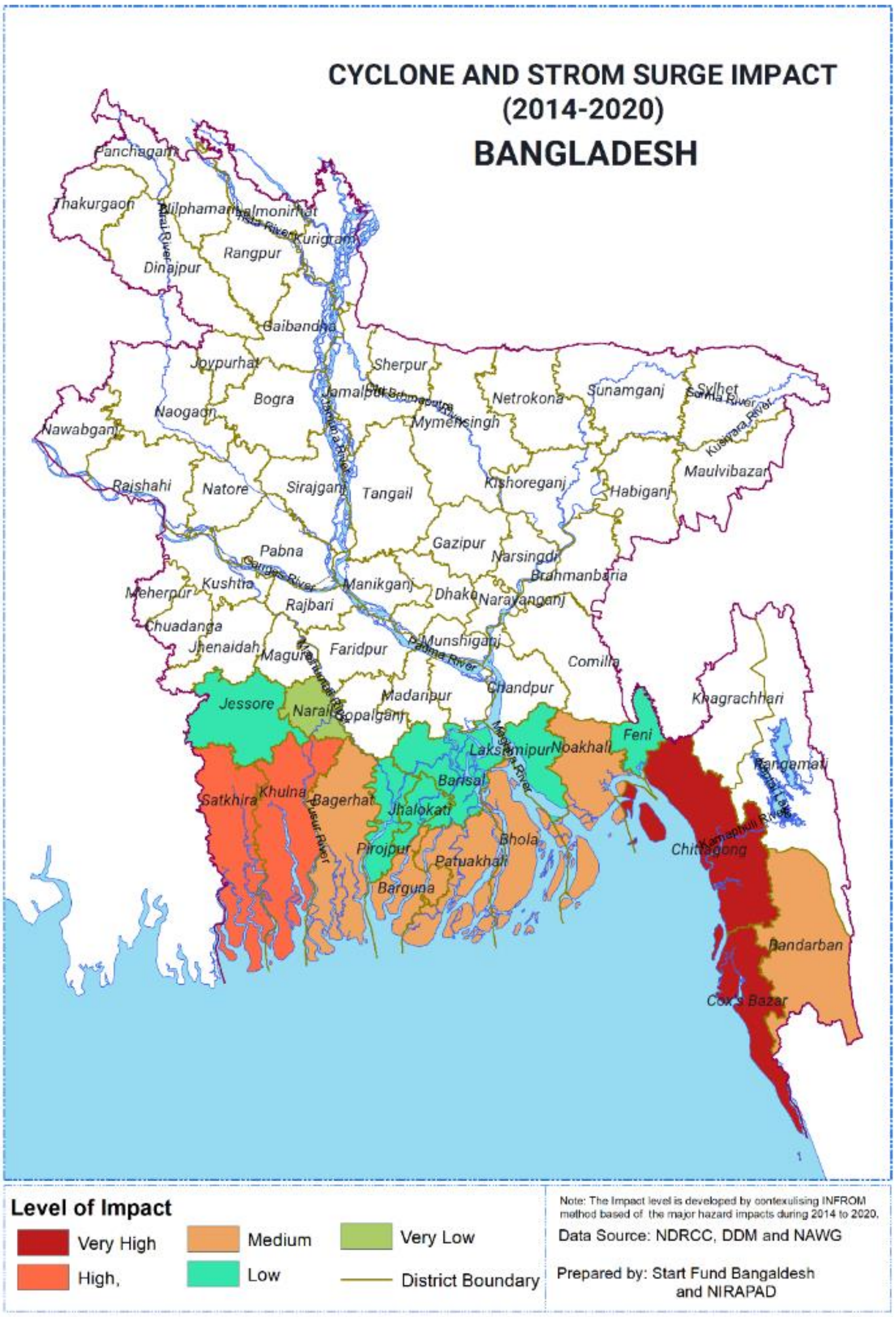
Monsoon floods and flash floods are also the most frequent climate-related disaster in Bangladesh. The risk index produced a very high impact in 4 (10.53%) districts, high impact in 4 (10.53%) districts, medium in 14 (36.84%) districts, low in 12 (31.58%) districts, and very low in 4 (10.53%) districts.



Map 3.1: Flash and Flood Impact (2014-2020) of Bangladesh

3.2.2. Cyclone and Strom Surge Risk

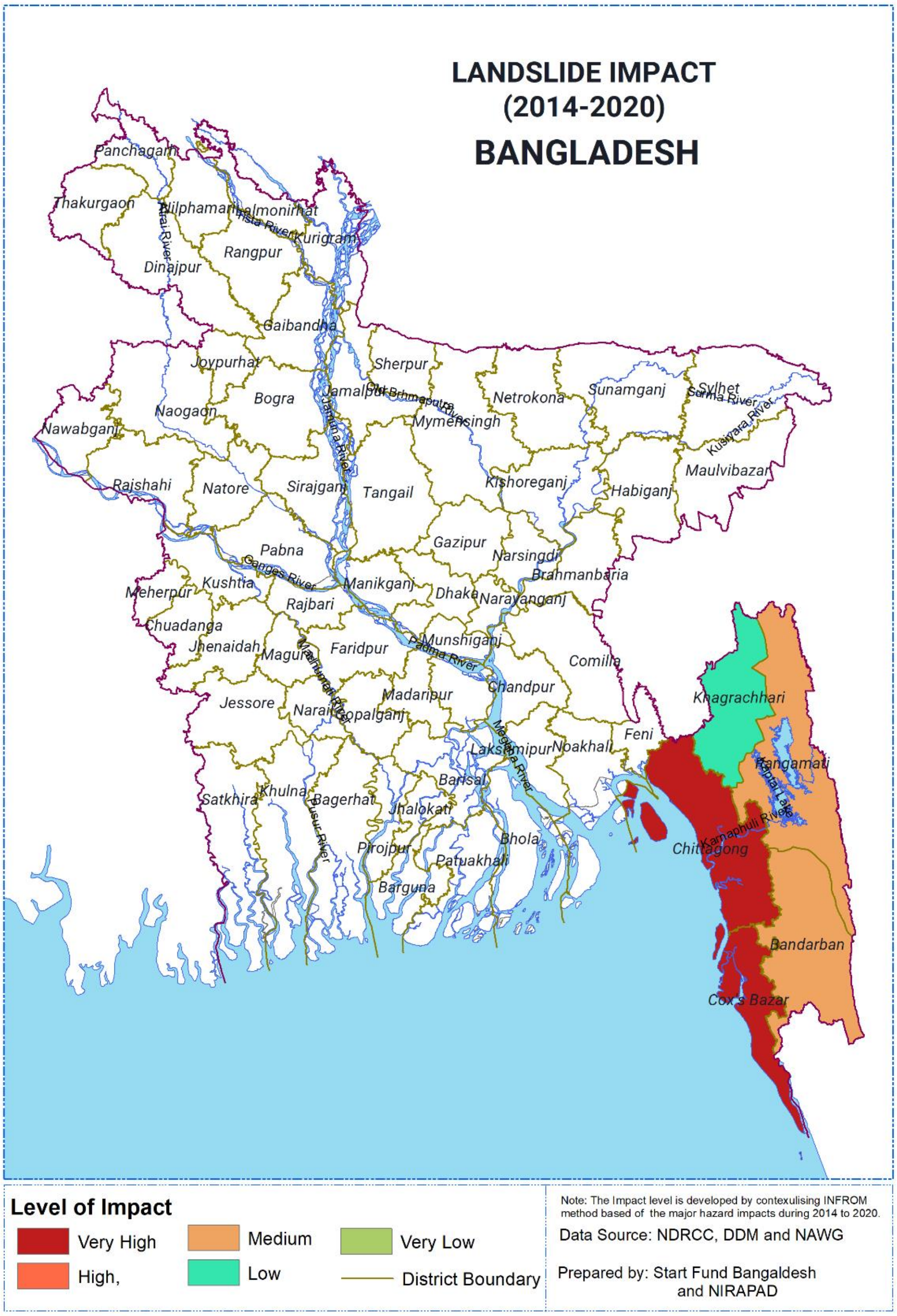
Cyclone and storm surges are the most frequent climate-related disasters in Bangladesh. The calculated risk index for cyclone and storm surge based on 7 indicators resulted in very high impact in 2 (11.74%) districts, high impact in 2 (11.76%) districts, medium impact in 6 (35.29%) districts, low in 6 (35.29%) districts, and very low impact in 1 (5.80%) district.



Map 3.2: Cyclone and Storm Surge Impact (2014-2020) of Bangladesh

3.2.3. Landslide Risk

Landslides become a major concern for the hilly areas of the country. The calculated risk index for landslide based on 7 indicators resulted in very high impact in 2 (40.0%) districts, medium impact in 2 (40.0%) districts and low in 1 (20.0%) district.

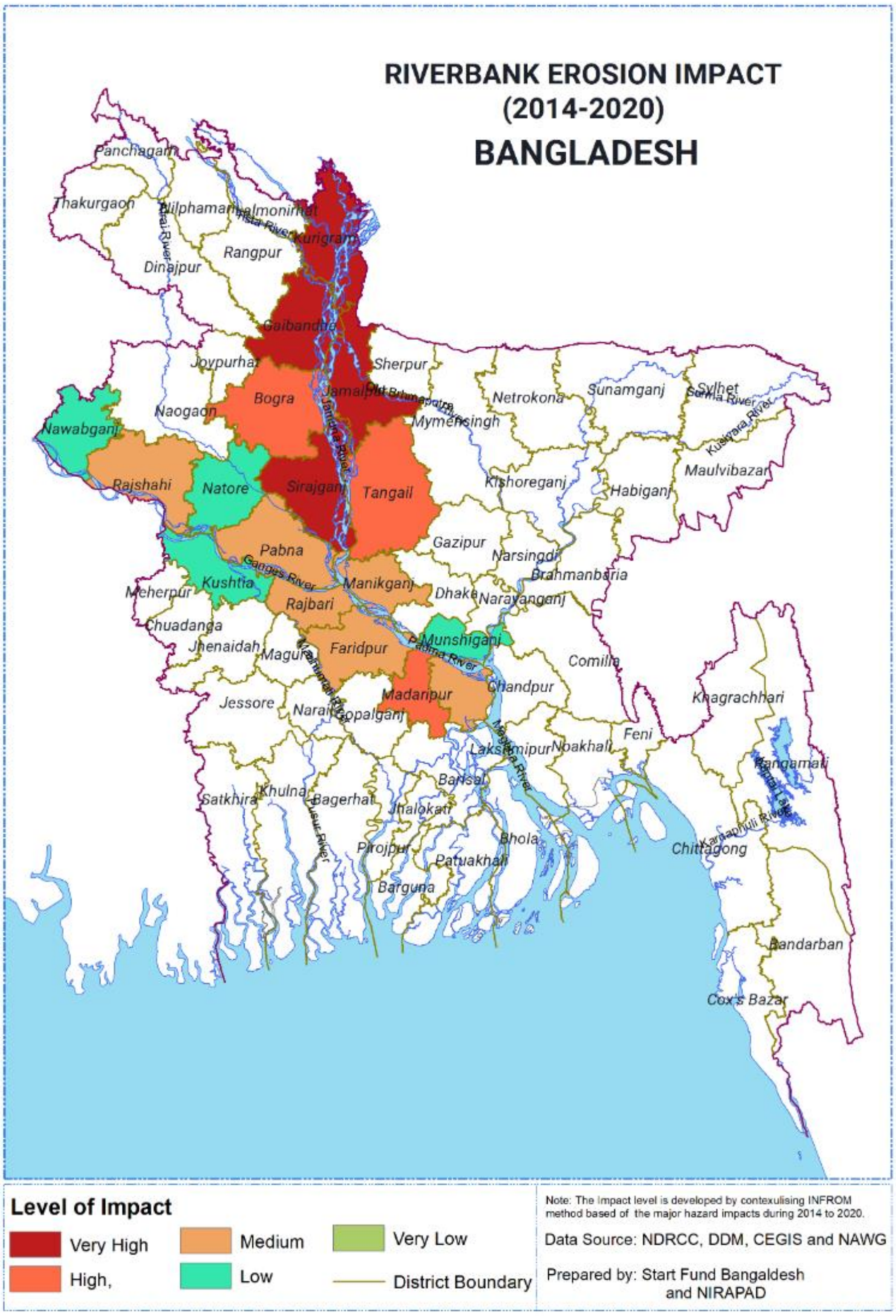


Map 3.3: Landslide Impact (2014-2020) of Bangladesh

3.2.4 Riverbank Erosion Risk

Riverbank erosion is associated with flood impact in Bangladesh. Every year, millions of people are affected in the seventeen districts that are prone to riverbank erosion. It causes loss and damage to crops and cropland, cattle, and houses. Additionally, it erodes public infrastructure and hampers communication systems.

The calculated risk index for riverbank erosion resulted in a very high impact in 4 (23.53%) districts, high impact in 3 (17.65%) districts, medium in 6 (35.29%) districts, and low impact in 4 (23.53) districts.



Map 3.4: Riverbank Erosion Impact (2014-2020) of Bangladesh

3.3. Hazards Exposure

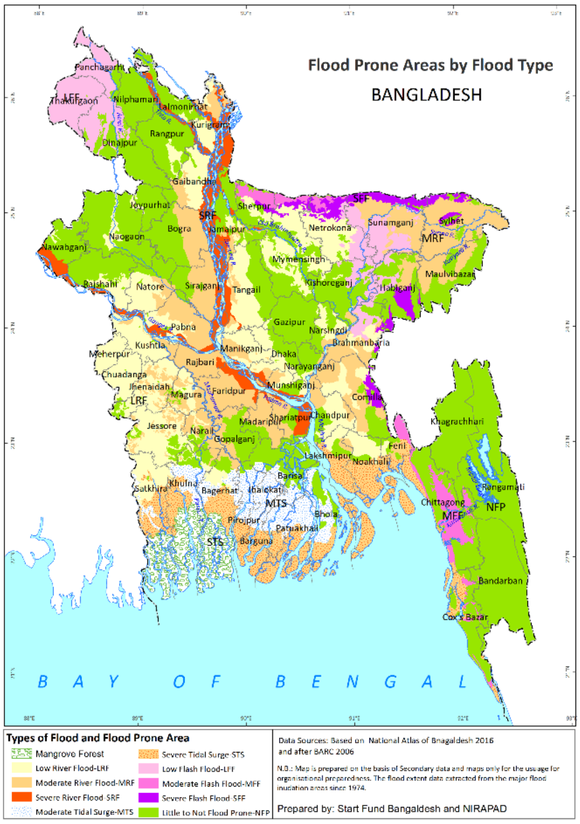
Exposure can be explained by the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected by disasters (Zebisch et al., 2017). The degree of exposure can be expressed by absolute numbers, densities, or proportions, etc. of the elements at risk (e.g., population density in an area affected by flood). A change in exposure over time (e.g., change in the number of people living in flood-prone areas) can significantly increase or decrease risk.

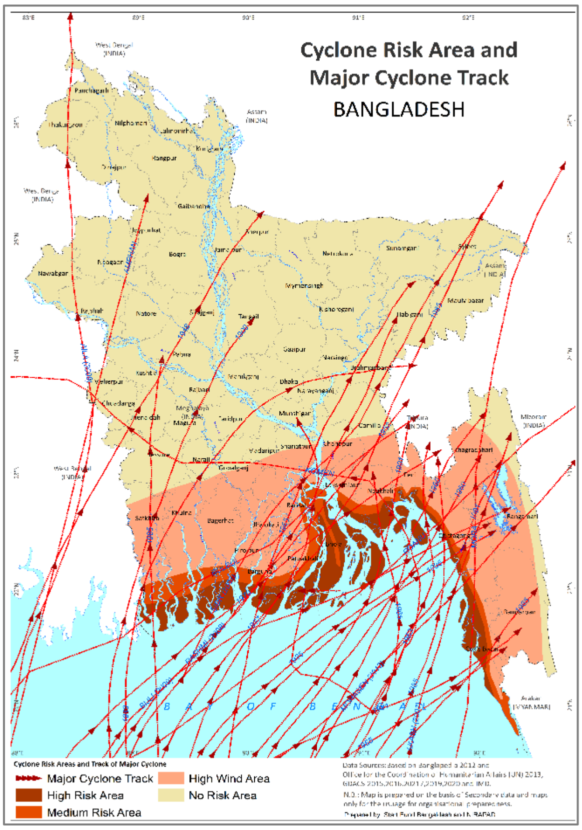
- Exposure is related to specific exposed elements (or elements at risk), e.g., people, infrastructure, ecosystems.
- The degree of exposure can be expressed by absolute numbers, densities or proportions, etc. of the elements at risk (e.g., population density in an area affected by flood).
- A change in exposure over time (e.g., change of number of people living in flood-prone areas) can significantly increase or decrease risk.

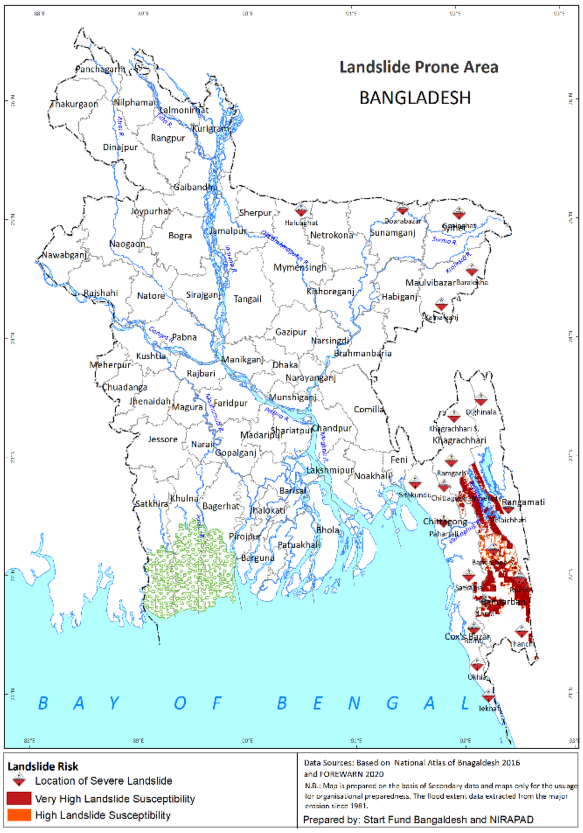
Population exposure to hazard is defined, for example, as the likelihood that an individual in a given location is exposed to a given type of climate-related hazard over a certain period of time. Mapping the extent of a natural hazard (e.g., assessing areas with high risk) or disaster is the first step in disaster risk management and emergency response. Subsequently, exposure mapping enables the estimation of the impact of hazards or disasters, for example, regarding the number of affected inhabitants or infrastructure. The following practice shows the use of Quantum GIS to analyze a disaster extent map in combination with auxiliary data such as population or land cover data. Bangladesh, mostly by the virtue of its geophysical features, is a disaster-prone country which coupled with the global climate change poses a major threat for its residents and their livelihoods.

For climate-related multi-hazard exposure, is assessed available updated Government maps based on risk modeling that considered climate change impacts. For calculating exposure, a total of eight indicators were used, are- 1. possible hazards frequency areas, 2. probable number of populations exposed, 3. probable area of exposure, 4. possible area of inundation, 5. landslide susceptibility, 6. river erosion-prone areas, 7. probable area of exposed cropland, 8. char land areas.

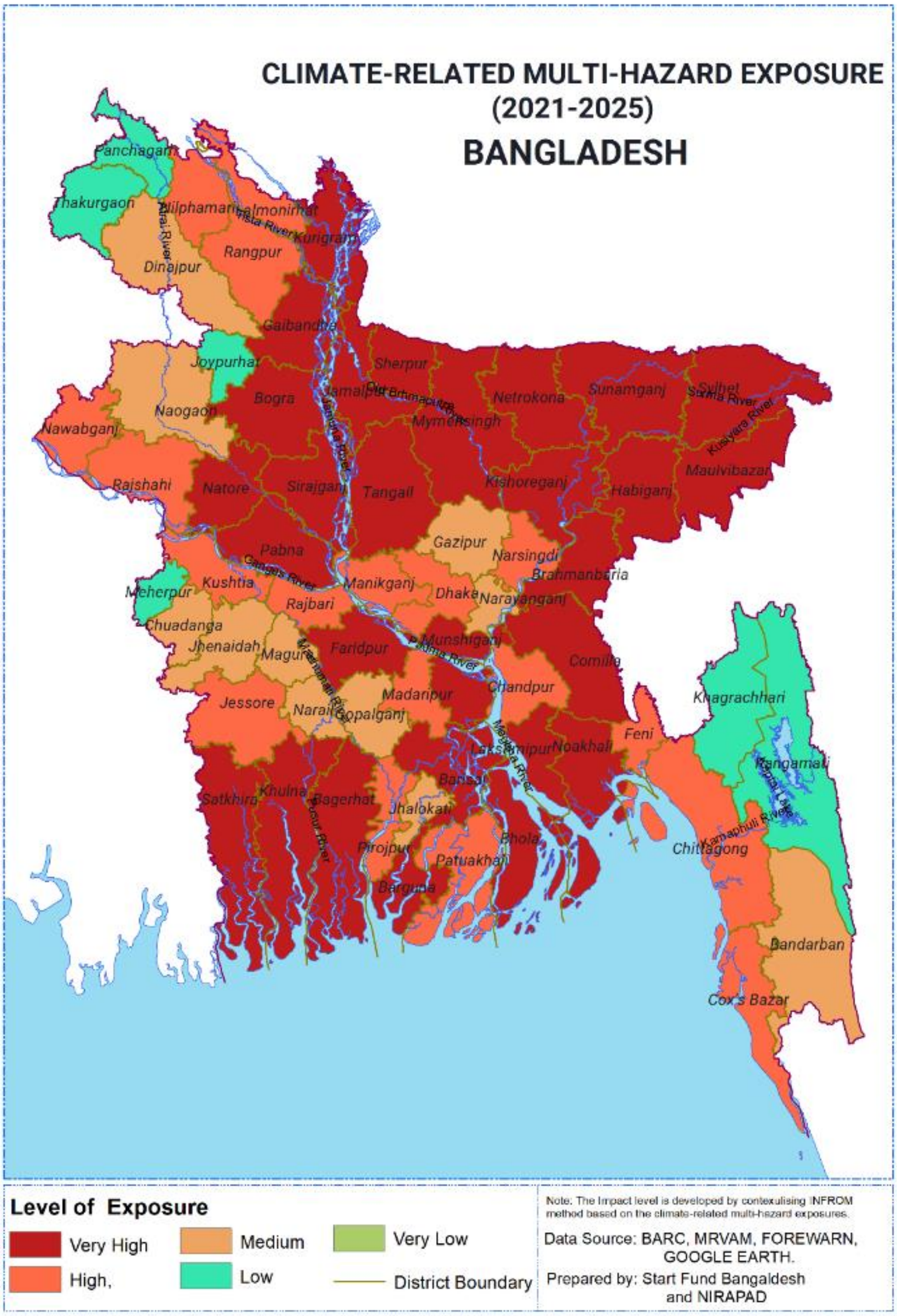
Map 3.5: Climate-Related Hazard Specific Exposure Map of Bangladesh







The hazard exposure map illustrates that every district of the country is exposed to an individual or several types of hazards. In addition, with its low elevation, high population density, and inadequate infrastructure Bangladesh is highly exposed to climate-related hazards. The climate-related multi-hazard exposure index is based on 8 exposure-related indicators. The result shows very high exposure in 29 (45.31) districts, high in 18 (28.13) districts, medium in 11 (17.19%) districts, and low exposure in 6 (9.38%) districts.



Map 3.6: Climate-Related Multi-Hazard Exposure (2021-2025) of Bangladesh

3.4. Socio-Economic Vulnerability

The Sendai Framework recommendations adopted by the UN General Assembly in 2016 defined vulnerability as "the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards." Vulnerability is an extension of initial exposure statistics by adding statistics on relevant characteristics, or disaggregation of the population, infrastructure, or land uses exposed to a hazard, i.e., by sex, age, income, and disability. According to the IPCC AR5 report, vulnerability has two relevant elements: sensitivity and capacity.

Sensitivity is determined by those factors that directly affect the consequences of a hazard. Sensitivity may include physical attributes of a system (e.g., building material of houses, type of soil on agriculture fields), social, economic, and cultural attributes (e.g., age structure, income structure).

Capacity in the context of climate-related risk assessments refers to the ability of societies and communities to prepare for and respond to current and future climate-related impacts. It comprises:

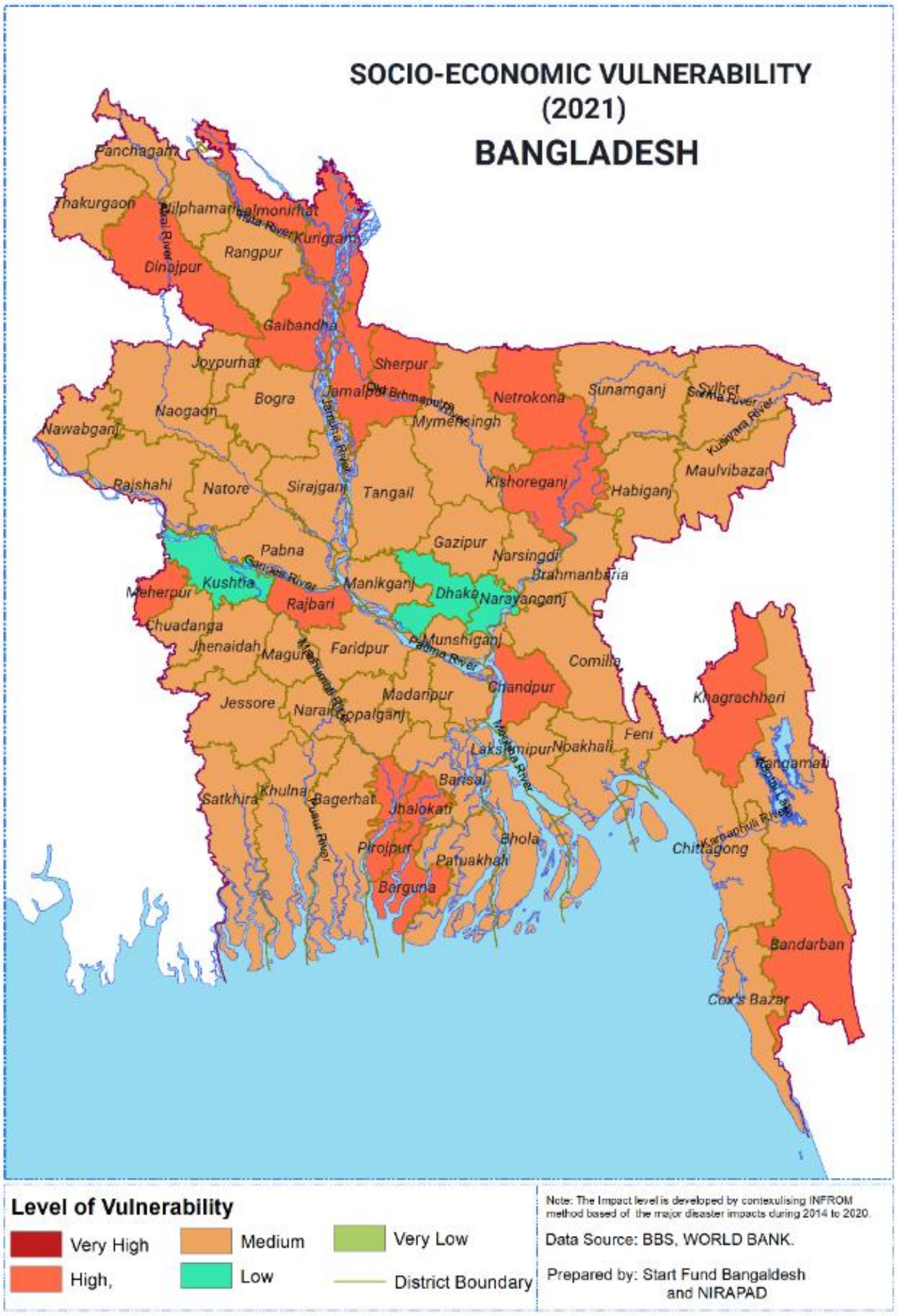
(a) *Coping capacity*: 'The ability of people, institutions, organizations, and systems, using available skills, values, beliefs, resources, and opportunities, to address, manage, and overcome adverse conditions in the short to medium term (e.g., early warning systems in place).

(b) *Adaptive capacity*: 'The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (e.g., knowledge to introduce new farming methods).

Many social and economic factors affect vulnerability such as the age of a person at the time of the disaster, or persons with disabilities which can be significantly important in situations where physical fitness is necessary for survival. Gender can be a factor, for example, the emergence of violence and sexual abuse after disasters on women has been documented. Poverty, which correlates with less healthy and less safe environments plus poor education is another possible factor. This report considered socio-economic vulnerability-related indicators in three broader dimensions- 1. living standards, 2. coping mechanism, and 3. physical and mental wellbeing.

A total of nine indicators were considered for the calculation of socio-economic vulnerability. The nine indicators are 1. poor people (extreme or upper poor), 2. household dietary diversity score (different food groups), 3. dwelling structure (Jhupri, katcha, semi-pucca and pucca), 3. livelihoods (day labours, self-employed, employee, and employer), 4. women-headed households, 5. ethnic population, 6. persons with disability h. elderly persons, 7. prevalence of undernourishment.

The vulnerability index-based map shows that all the districts of Bangladesh have a level of vulnerability, high to low. Out of 64 districts, 16 (25.0%) districts show high, 45 (70.31) districts medium and 3 (4.69) districts are in the low category.



Map 3.7: Socio-Economic Vulnerability (2021) of Bangladesh

3.5. Multi-Hazard Risk

Climate-related hazards have the potential for causing specific, climate-related consequences (climate impacts) to something of value (i.e., assets, people, ecosystem, culture, etc.). Typically, the system will be affected by more than one climate-related hazard. This basic definition for assessment of risk has also been known as the Pressure and Release (PAR) model (Birkman, 2013). Disaster risk impacts are not driven only by the magnitude of the hazard (e.g., category of the storm) but also by social factors that create exposure, vulnerability, and coping capacity (UNDRR, 2015).

An impact chain is an analytical tool that helps to better understand, systemize, and prioritize the factors that drive risk in the concerned system. It is composed of risk components (hazard, vulnerability, exposure) (see colored containers in Figure 3.4) and underlying factors (white boxes). The hazard component includes factors related to the climate signal and direct physical impact. The vulnerability components consist of sensitivity and capacity factors. The exposure component is comprised of one or more exposure factors (no subdivision within this component). For simplicity, the relationships from all factors directly lead to the risk without relationships to other factors and they are summarized by bold arrows on the bottom of the respective components.

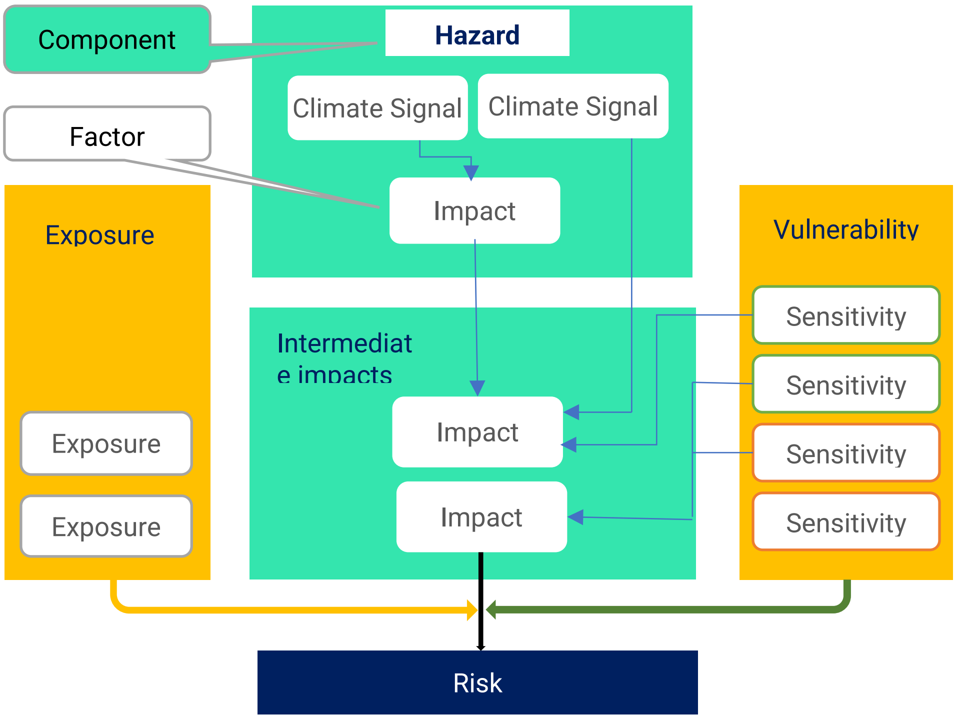
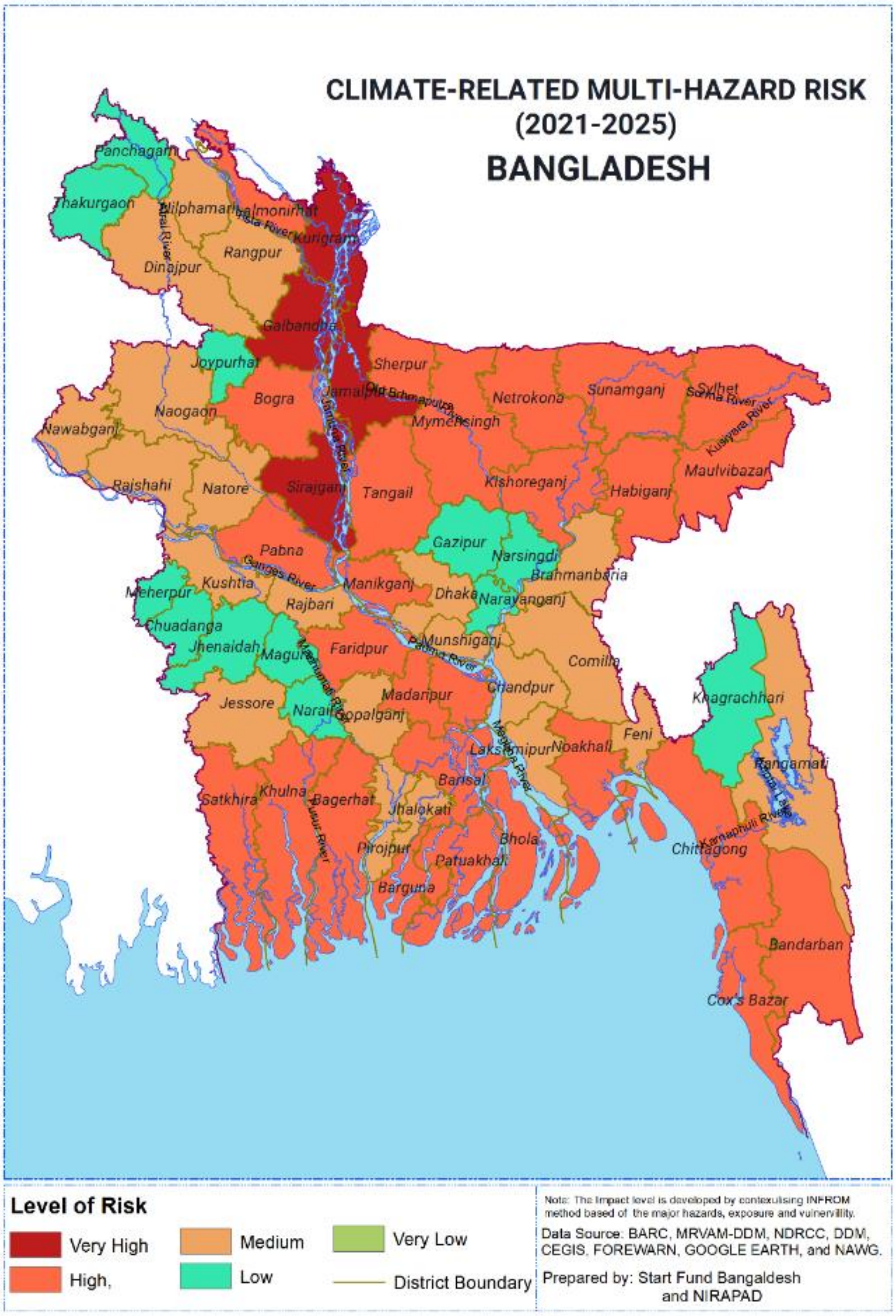


Figure 3.3: Climate-related multi-hazard risk

The climate-related multi-hazard risk analysis considered all three aspects of the impact chain. The overall climate-related multi-hazard risk index identifies districts at risk from humanitarian crises and disasters that could overwhelm response capacity. It is made up of three dimensions- hazard and exposure, vulnerability, and lack of coping capacity. From the multi-hazard index, a multi-hazard map has been developed which illustrates the districts from very high to very low risks (click here to see the multi-hazard risk analysis dataset). The multi-hazard risk map is showing that several districts in the north and northeast of Bangladesh are at very high risk. In contrast, only one district of the southern region of Bangladesh possesses a very high risk.

Table 3.1: Number of districts in climate-related multi-hazard risk

Risk Level	Number of Districts	District (%)
Very High	4	6.25
High	27	42.19
Medium	21	32.81
Low	12	18.75
Total	**64**	**100**



Map 3.8: Climate-Related Multi-Hazard Risk (2021-2025) of Bangladesh

4. FORECASTED PEOPLE IN NEED

4.1. Overview

The multi-hazard risk analysis for quantifying the risk, based on the two forces, its hazards and the exposure of people and other side is the vulnerability of people to those hazards including lack of capacity to cope with them. Risk analysis provides the choice of geographical areas for actions. Risk analysis does not tell us about the target population according to the severity. The climate-related hazard risk based on the deterministic impact population data (2014-2020) on last seven years showed that the hazards that impacted the population vary significantly- ranging from 5 to 778 per thousand people. Based on this impact distribution data, transforming to standard distribution curve, the researchers have reached an inference that 660 per 1,000 people (95 percent confidence intervals) will be impacted by climate-related hazards annually in the next five years. Figure 4.1 shows the distribution and confidence curve that has been used for this inference.

Based on the risk level and evidence-based convergence, this study estimated that annually 12.10 million people (2.71 million households) that could be potentially impacted out of 18.33 million people (4.10 million households) who will be annually exposed to climate-related multi-hazards.

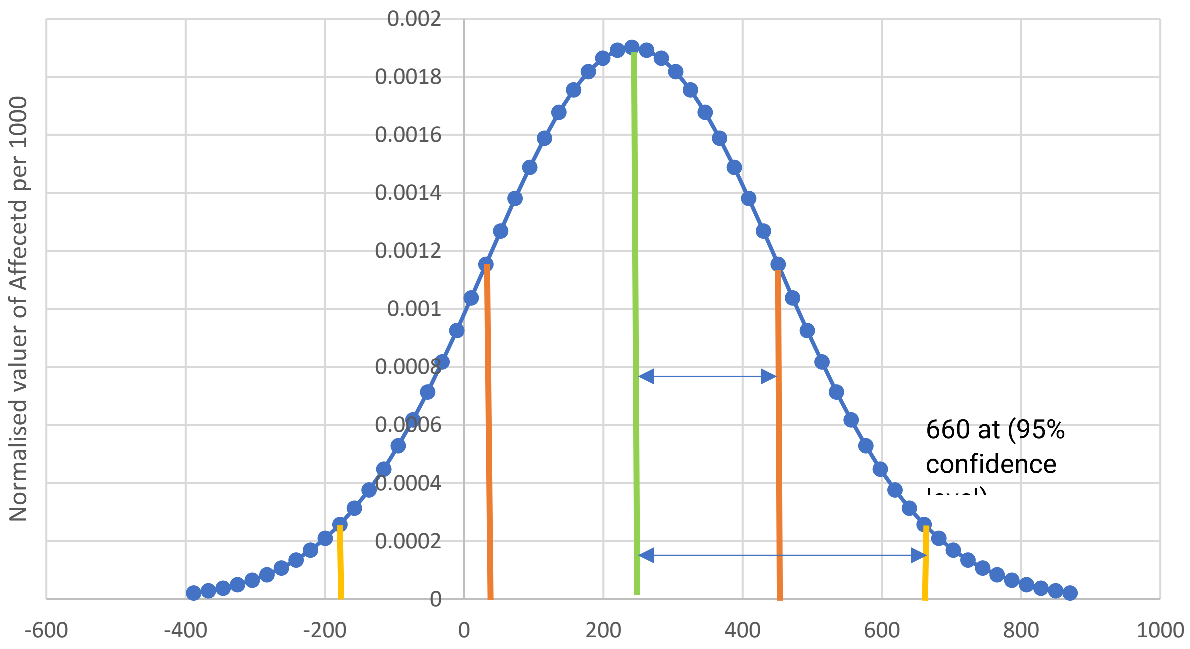


Figure 4.1: Normal distribution curve of affected population (2014-2020)

Inter-Agency Standing Committee's (IASC) Joint Intersectoral Analysis Framework (JIAF) provides a set of protocols, methods, and tools to classify the severity of people's conditions (including humanitarian needs). The severity of peoples' condition results from the risk of climate-related disasters or ongoing conditions. It helps to identify main drivers and underlying factors as well as provides actionable insights for decision making. In JIAF humanitarian conditions pillar is identified in terms of magnitude. It is analysed in terms of severity where the consequences of the shock/event's impact on people. This framework can also be used in unfolding climate-related disaster risk scenarios for better risk financing strategy and planning.

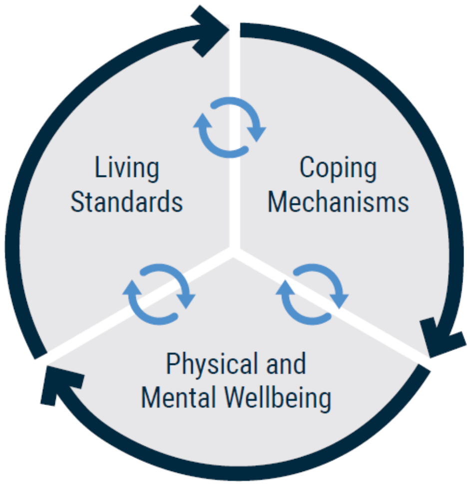


Figure 4.2: IASC humanitarian condition pillars

The severity of humanitarian conditions is estimated by considering three humanitarian consequences- (i) living standards, (ii) coping mechanisms, and (iii) physical and mental wellbeing. This study also estimated the severity of humanitarian conditions by considering the three humanitarian consequences suggested by JIAF: living standards, coping capacity, physical and mental wellbeing based on the available contextualized nine indicators as mentioned below:

Table 4.1: List of contextualized indicators used for forecasting priority needs

Living Standards **The ability of the affected population to meet their basic needs.**	The basic needs are measured using the following indicators: ▪ poor people ▪ household dietary diversity score ▪ dwelling structure
Coping Capacity **The degree to which individuals, households, communities, and systems are coping or facing challenges with impact recovery.**	The severity of the coping strategies is measured using the following indicators: ▪ livelihood groups ▪ poor female headed HHs ▪ ethnic population
Physical and Mental Wellbeing **This refers exclusively to information and indicators about the physical and mental health of the potential impact population.**	Physical and mental health is measured using the following indicators: ▪ persons with disability ▪ elderly persons, ▪ prevalence of undernourishment (severely stunted children)

4.2. Current and Forecasted Needs

The study measured intersectoral severity (the degree of harm brought by all combined climate-related hazard impacts) by applying the contextualized JIAF Severity Scale (illustrated on the following page). For each level (phase) in the scale, information from the three humanitarian conditions sub-pillars is combined to identify a degree of severity that is aligned to specific response objectives.

Table 4.2: Severity phase, outcome, and response

SEVERITY PHASE		KEY REFERENCE OUTCOME	POTENTIAL RESPONSE OBJECTIVES
1	Minimal	• Living Standards are acceptable: possibility of having some signs of deterioration and/or inadequate social basic services, possible needs for strengthening the legal framework. • Ability to afford/meet all essential basic needs without adopting • Unsustainable coping mechanisms. • No or minimal/low risk of impact on physical and mental wellbeing.	Building Resilience Supporting Disaster Risk Reduction
2	Stress	• Living Standards under stress, leading to adoption of coping strategies • Inability to afford/meet some basic needs without adopting stressed, unsustainable and/or short-term reversible Coping Mechanisms. • Minimal impact on Physical and Mental Well-being overall. • Possibility of having some localized/targeted incidents of violence (including human rights violations).	Supporting Disaster Risk Reduction Protecting Livelihoods
3	Severe	• Degrading Living Standards (from usual/typical), inability to meet some basic needs without adopting crisis/emergency short/medium term irreversible - Coping Mechanisms. • Reduced access/availability of social/basic goods and services. • Degrading Physical and Mental Wellbeing. Physical and mental harm resulting in a loss of dignity.	Protecting Livelihoods Mitigating Risk and Exposure of extreme deterioration of Humanitarian conditions
4	Extreme	• The collapse of Living Standards, with survival based on humanitarian assistance and/or long-term irreversible extreme coping strategies. • Extreme loss/liquidation of livelihood assets that will lead to large gaps/needs in the short term. • Widespread grave violations of human rights. Presence of irreversible harm and heightened mortality	Saving Lives and Livelihoods Reduce Exposure of loss

The severity analysis contributes to answering questions on where to allocate resources, to whom and to how many people, when, and on what should be done. The purpose of classifying severity and causes is to consolidate diverse data and methods into an analytical output statement that is comparable over space and time, and to answer the following questions:

- To inform contingency planning, mitigation, and prevention strategies.
- To inform response analysis and the strategic design of interventions.
- To inform targeting so that interventions are goes in the right place and to the right social groups.

The future projection of severity provided an early warning statement for proactive decision-making based on (1) building technical consensus, and (2) classifying severity and causes. The calculation of the potential district base impact population based on the vulnerability data in each district and help inform 'Situation Analysis'. Additional information is needed to conduct Household Economy Approach (HEA) for the decisions of response interventions. The below table is showing the calculation framework for district-wise potential population/households according to the severity of needs.

Table 4.3: Framework for calculating the severity of projected population in need

District	Major Hazard Type	Projected Potential Impact HH	Broader Dimensions	Indicator Name	1-Minimal	2-Stress	3- Severe	4-Extreme
District	Cyclone	Numbers	Living Standards	Income and Poverty HH	% Rest of the Population		% of Upper Poverty	% of Extreme Poor
				HH Dietary Diversity	% of HH consume Food Group >=7		% of HH consume Food Group = 5-6	% of HH consume Food Group <=4
				Housing Structure	Pucca (%)	Semi-Pucca (%)	Katcha (%)	Jhupri (%)
			Living Standards Convergence		%	%	%	%
			Coping Mechanism	HH Livelihoods	Employer HH %	Employee HH %	Self-employed HH %	Day Laborer HH %
				Women Headed HH	Household Other than Women Headed (%)		Women Headed HH (%)	Women Headed HH Poor and Extreme Poor (%)
				Ethnic HH	Other Population (%)			Ethnic Population (%)
			Coping Mechanism Convergence		%		%	%
			Physical and Mental Wellbeing	Status of Person with Disability (pop)	Other Population (%)			Person with Disability (%)
				Age Group (pop)	Pop Age 19 to 49 %	Pop Age 50 to 64%	Pop Age Over 65%	Pop age Upto 18 %
				Under Nourishment HH	Other Population		Moderately Stunted %	Severely Stunted 4 %
			Physical and Mental Wellbeing Convergence		%	%	%	%
Overall Convergence					%	%	%	%
Convergence (Number Pop)					#	#	#	#

4.3. Hazard Based Severity Ranking

A consensus was developed regarding nine indicators for justifying its actionability at the district level (further it could be used at the upazila and union level) with the clusters, working group coordinators, and Start Fund Bangladesh members.

This joint ownership will contribute to a well-coordinated humanitarian response. Findings based on the assessment of climate-related hazards of the district-based exercise is given below for the potentially impacted household based on the severity ranking:

Table 4.4: Annual projected households in need by types of hazards

Type of Hazard	Number of Districts	Number of Household				Total Potential Impact HH
		Minimal #	Stress #	Severe #	Extreme #	
Cyclone and Strom Surge	17	104,919	145,935	180,299	152,409	583,562
Flood and Riverbank Erosion (17 Districts are Riverbank Erosion Prone)	45	337,998	484,784	730,044	570,317	2,123,144
Landslide (3 Districts overlapped with Cyclone and Strom Surge)	5	18,680	23,501	27,381	23,557	93,119
Total (no overlap)	**64**	**443,502**	**631,761**	**912,553**	**724,736**	**2,712,553**

Finally, the potential annually impacted population by climate-related hazards has been classified according to the four-severity phases (click here for full dataset). Below table shows the hazard wise rank of districts household distribution forecasted impact according to the severity:

Table 4.5: District wise annual projected households in need by floods and riverbank erosion

Serial No.	District Name	Major Primary Disaster Type	Major Secondary Disaster Type	Multi-Hazard Risk Index	Multi-Hazard Risk level	Rank Multi-Hazard Risk	Rank For Flood	Rank for Flash Flood	1-Minimal (% of HH)	2-Stress (% of HH)	3- Severe (% of HH)	4-Extreme (% of HH)	1-Minimal (# of HH)	2-Stress (# of HH)	3- Severe (# of HH)	4-Extreme (# of HH)	Total Potential Impact HH
1.	Kurigram	Flood	Riverbank Erosion	7.2	Very High	1	1		10	15	35	40	16,911	25,366	59,187	67,643	169,107
2.	Jamalpur	Flood	Riverbank Erosion	7.0	Very High	2	2		5	15	45	35	6,858	20,575	61,724	48,007	137,164
3.	Gaibandha	Flood	Riverbank Erosion	6.6	Very High	3	3		10	15	35	40	13,494	20,241	47,230	53,977	134,943
4.	Sirajganj	Flood	Riverbank Erosion	6.5	Very High	4	4		20	20	30	30	24,306	24,306	36,458	36,458	121,528
5.	Sunamganj	Flood	Flash Flood	6.4	High	5	5	1	15	20	35	30	8,070	10,760	18,831	16,141	53,802
6.	Tangail	Flood	Riverbank Erosion	6.1	High	6	6		20	30	30	20	16,875	25,312	25,312	16,875	84,373
7.	Netrakona	Flood	Flash Flood	5.9	High	7	7	2	15	20	35	30	7,692	10,256	17,947	15,384	51,278
8.	Sylhet	Flood	Flash Flood	5.9	High	7	8	3	15	30	30	25	11,192	22,383	22,383	18,653	74,610
9.	Bogura	Flood	Riverbank Erosion	5.6	High	10	9		15	20	40	25	4,837	6,449	12,897	8,061	32,244

Serial No.	District Name	Major Primary Disaster Type	Major Secondary Disaster Type	Multi-Hazard Risk Index	Multi-Hazard Risk level	Rank Multi-Hazard Risk	Rank For Flood	Rank for Flash Flood	1-Minimal (% of HH)	2-Stress (% of HH)	3- Severe (% of HH)	4-Extreme (% of HH)	1-Minimal (# of HH)	2-Stress (# of HH)	3- Severe (# of HH)	4-Extreme (# of HH)	Total Potential Impact HH
10.	Faridpur	Flood	Riverbank Erosion	**5.4**	**High**	*14*	10		20	30	30	20	8,888	13,332	13,332	8,888	44,439
11.	Pabna	Flood	Riverbank Erosion	**5.4**	**High**	*14*	11		25	25	30	20	13,957	13,957	16,749	11,166	55,829
12.	Habiganj	Flood	Flash Flood	**5.3**	**High**	*18*	13	4	15	25	35	25	6,864	11,440	16,016	11,440	45,761
13.	Mymensingh	Flood		**5.3**	**High**	*18*	12		20	25	35	20	41,459	51,824	72,553	41,459	207,294
14.	Maulvibazar	Flood	Flash Flood	**5.2**	**High**	*20*	15	5	20	25	35	20	8,812	11,015	15,421	8,812	44,061
15.	Madaripur	Flood	Riverbank Erosion	**5.2**	**High**	*20*	14		25	30	30	15	5,521	6,626	6,626	3,313	22,085
16.	Sherpur	Flood	Flash Flood	**5.1**	**High**	*22*	16	6	15	20	35	30	7,981	10,641	18,623	15,962	53,207
17.	Manikganj	Flood	Riverbank Erosion	**5.0**	**High**	*24*	18		20	20	35	25	2,775	2,775	4,856	3,468	13,873
18.	Shariatpur	Flood	Riverbank Erosion	**5.0**	**High**	*24*	19		10	30	40	20	4,483	13,448	17,931	8,965	44,827
19.	Kishoregonj	Flood		**5.0**	**High**	*24*	17		10	20	40	30	5,633	11,266	22,532	16,899	56,330
20.	Lalmonirhat	Flood		**5.0**	**High**	*24*	20		10	20	40	30	2,690	5,380	10,761	8,071	26,902
21.	Rajbari	Flood	Riverbank Erosion	**4.9**	**Medium**	*32*	22		25	25	30	20	5,500	5,500	6,600	4,400	22,001
22.	Chandpur	Flood		**4.9**	**Medium**	*32*	21		20	25	35	20	10,711	13,389	18,745	10,711	53,557
23.	Rajshahi	Flood	Riverbank Erosion	**4.8**	**Medium**	*34*	23		20	25	30	25	7,713	9,642	11,570	9,642	38,567
24.	Rangpur	Flood		**4.8**	**Medium**	*34*	24		5	25	40	30	3,985	19,925	31,880	23,910	79,699
25.	Natore	Flood	Riverbank Erosion	**4.7**	**Medium**	*36*	25		15	25	30	30	4,955	8,258	9,909	9,909	33,031
26.	Munshiganj	Flood	Riverbank Erosion	**4.6**	**Medium**	*39*	27		15	25	30	30	2,675	4,458	5,349	5,349	17,830
27.	Brahmanbaria	Flood		**4.6**	**Medium**	*39*	26		25	25	30	20	7,773	7,773	9,327	6,218	31,091
28.	Cumilla	Flood		**4.5**	**Medium**	*41*	28		20	25	35	20	16,912	21,139	29,595	16,912	84,558
29.	Dhaka	Flood		**4.3**	**Medium**	*42*	29		30	30	30	10	17,664	17,664	17,664	5,888	58,880

Serial No.	District Name	Major Primary Disaster Type	Major Secondary Disaster Type	Multi-Hazard Risk Index	Multi-Hazard Risk level	Rank Multi-Hazard Risk	Rank For Flood	Rank for Flash Flood	1-Minimal (% of HH)	2-Stress (% of HH)	3- Severe (% of HH)	4-Extreme (% of HH)	1-Minimal (# of HH)	2-Stress (# of HH)	3- Severe (# of HH)	4-Extreme (# of HH)	Total Potential Impact HH
30.	Dinajpur	Flood		**4.3**	**Medium**	*42*	30		10	25	30	35	5,616	14,040	16,848	19,656	56,161
31.	Nilphamari	Flood		**4.3**	**Medium**	*42*	31		20	25	35	20	6,021	7,526	10,537	6,021	30,105
32.	Naogaon	Flood		**4.2**	**Medium**	*46*	32		10	25	35	30	1,635	4,087	5,722	4,905	16,350
33.	Nawabganj	Flood	Riverbank Erosion	**4.2**	**Medium**	*46*			15	25	30	30	2,452	4,087	4,905	4,905	16,349
34.	Gopalganj	Flood		**3.7**	**Medium**	*51*	33		25	25	30	20	5,560	5,560	6,672	4,448	22,239
35.	Kushtia	Flood	Riverbank Erosion	**3.6**	**Medium**	*52*	34		30	30	25	15	436	436	363	218	1,454
36.	Thakurgaon	Flood		**3.3**	**Low**	*53*	35		15	20	40	25	1,241	1,654	3,309	2,068	8,271
37.	Gazipur	Flood		**3.2**	**Low**	*54*	36		25	25	30	20	4,418	4,418	5,301	3,534	17,670
38.	Panchagarh	Flood		**3.1**	**Low**	*57*	37		20	30	30	20	1,078	1,616	1,616	1,078	5,388
39.	Narsingdi	Flood		**3.1**	**Low**	*57*			30	25	35	10	3,300	2,750	3,850	1,100	11,001
40.	Magura	Flood		**2.8**	**Low**	*59*			15	25	30	30	1,457	2,428	2,913	2,913	9,711
41.	Chuadanga	Flood		**2.6**	**Low**	*60*			20	30	30	20	1,097	1,645	1,645	1,097	5,484
42.	Jhenaidah	Flood		**2.6**	**Low**	*60*			20	30	25	25	1,552	2,328	1,940	1,940	7,759
43.	Joypurhat	Flood		**2.6**	**Low**	*60*			15	25	40	20	831	1,384	2,215	1,108	5,538
44.	Narayanganj	Flood		**2.4**	**Low**	*63*	38		25	35	25	15	3,817	5,343	3,817	2,290	15,267
45.	Meherpur	Flood		**2.3**	**Low**	*64*			20	25	25	30	304	380	380	456	1,521
												Total	**337,998**	**484,784**	**730,044**	**570,317**	**2,123,144**

Table 4.6: District wise annual projected households in need by cyclone and storm surge

S. N.	District Name	Major Primary Disaster Type	Major Secondary Disaster Type	Multi-Hazard Risk Index	Multi-Hazard Risk level	Rank Multi-Hazard Risk	Rank For Cyclone	Rank for Landslide	1-Minimal %	2-Stress %	3- Severe %	4-Extreme %	1-Minimal #	2-Stress #	3- Severe #	4-Extreme #	Total Potential Impact HH
1.	Khulna	Cyclone		5.7	High	9	1		20	30	30	20	11,153	16,729	16,729	11,153	55,765
2.	Cox's Bazar	Cyclone	Landslide	5.6	High	10	2	1	20	25	25	30	8,383	10,479	10,479	12,575	41,916
3.	Chattogram	Cyclone	Landslide	5.5	High	12	4	2	25	30	30	15	8,628	10,354	10,354	5,177	34,513
4.	Barguna	Cyclone		5.5	High	12	3		10	25	40	25	2,349	5,873	9,396	5,873	23,491
5.	Noakhali	Cyclone		5.4	High	14	5		20	25	25	30	2,358	2,948	2,948	3,537	11,792
6.	Satkhira	Cyclone		5.4	High	14	6		15	30	25	30	10,969	21,938	18,282	21,938	73,128
7.	Patuakhali	Cyclone		5.1	High	22	7		10	25	40	25	2,641	6,601	10,562	6,601	26,405
8.	Bandarban	Cyclone	Landslide	5.0	High	24	10	3	10	15	40	35	1,084	1,626	4,337	3,795	10,843
9.	Barishal	Cyclone		5.0	High	24	8		20	20	30	30	19,993	19,993	29,989	29,989	99,965
10.	Bhola	Cyclone		5.0	High	24	9		20	20	35	25	7,821	7,821	13,687	9,776	39,105
11.	Bagerhat	Cyclone		5.0	High	24	11		15	20	35	30	6,048	8,064	14,111	12,095	40,318
12.	Pirojpur	Cyclone		4.7	Medium	36	12		20	25	35	20	5,222	6,528	9,139	5,222	26,111
13.	Lakshmipur	Cyclone		4.7	Medium	36	13		10	20	40	30	2,504	5,007	10,014	7,511	25,036
14.	Feni	Cyclone		4.3	Medium	42	14		20	30	20	30	4,567	4,567	3,806	2,283	15,222
15.	Jhalokati	Cyclone		4.1	Medium	48	15		15	25	35	25	2,056	3,426	4,796	3,426	13,704
16.	Jashore	Cyclone		4.1	Medium	48	16		20	30	25	25	8,826	13,238	11,032	11,032	44,128
17.	Narail	Cyclone		3.2	Low	54	17		15	35	30	20	318	742	636	424	2,120
												Total	**104,919**	**145,935**	**180,299**	**152,409**	**583,562**

Table 4.7: District wise annual projected households in need by landslide

S. N.	District Name	Major Primary Disaster Type	Major Secondary Disaster Type	Multi-Hazard Risk Index	Multi-Hazard Risk level	Rank Multi-Hazard Risk	Rank For Cyclone	Rank for Landslide	1-Minimal %	2-Stress %	3- Severe %	4-Extreme %	1-Minimal #	2-Stress #	3- Severe #	4-Extreme #	Total Potential Impact HH
1.	Cox's Bazar	Cyclone	Landslide	5.6	High	*10*	2	1	20	25	25	30	8,383	10,479	10,479	12,575	41,916
2.	Chattogram	Cyclone	Landslide	5.5	High	*12*	4	2	25	30	30	15	8,628	10,354	10,354	5,177	34,513
3.	Bandarban	Cyclone	Landslide	5.0	High	*24*	10	3	10	15	40	35	1,084	1,626	4,337	3,795	10,843
4.	Rangamati	Landslide	Landslide	4.0	Medium	*50*		4	10	20	40	30	329	658	1,316	987	3,290
5.	Khagrachhari	Landslide	Landslide	3.2	Low	*54*		5	10	15	35	40	256	384	895	1,023	2,558
												Total	**18,680**	**23,501**	**27,381**	**23,557**	**93,119**

4.4. Coping and Adaptive Strategy

The people who live in hazard-prone places have to deal with various types of disasters periodically such as monsoon and flash flood, cyclone and storm surge, landslide and riverbank erosion. These disasters are seasonal (see Table xx). Flash floods occur during pre-monsoon (April-May) while monsoon flood affects the country during the monsoon (June-September). Cyclones generally strike Bangladesh in two seasons, pre-monsoon (April-May) and post-monsoon (October-November). More riverbank erosion occurs in the monsoon (June to September). Rain-triggered landslides occur in the southeastern hilly region during the monsoon season that generally lasts between June and September.

Table 4.8: Seasonal Calendar of major hazards and livelihoods

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Season		Winter	Winter	Winter	Pre-Monsoon	Pre-Monsoon	Monsoon	Monsoon	Monsoon	Monsoon	Post-Monsoon	Post-Monsoon	Winter
Hazards	Flood				■	■	■	■	■	■			
Hazards	Cyclone				■	■					■	■	
Hazards	Riverbank Erosion						■	■	■	■			
Hazards	Landslide						■	■	■	■			
Livelihoods	Aman Rice						Medium	Medium / Low	Low	Low	Low	High	
Livelihoods	Boro Rice	Low	Low	Low	High	High						Medium	Medium / Low
Livelihoods	Fishing	High	High	Low	Low	Low	High	High	High	Medium	Low	Medium	Medium
Livelihoods	Petty Trade	Medium	Medium	Medium	Medium	Medium	Low	Low	Low	Low	Medium	Medium	Medium

These hazards affect the rural livelihoods seasonally (see Table xx). Most of the households lose their income through loss of standing crops (*aman* and *boro* rice) and reduction in their employment opportunities due to hazards such as flash flood, monsoon flood and cyclone. It is mainly because hazards, particularly, flash flood, flood and cyclone decrease the labor for planting and harvesting of *aman* and *boro* rice; as a result, the employment opportunities for farm-based wage labor decline. In addition, riverbank erosion erode cropland every year. Petty trading and fishing are important livelihood options for many of the communities throughout the year that can also be disrupted due to monsoon flooding and cyclones.

Table 4.9: Impacts of major hazards on livelihoods

Types of hazards	Geographical Prevalence	Season	Impacts on Livelihoods
Monsoon Flood and Flash Flood	River Basin, Charland and Haor Region	Monsoon (June-September) and Pre-monsoon (April-May)	*Aman* and *Boro* rice damaged, farm-based wage labor declined, petty trade and fishing disrupted
Cyclone and Storm Surge	Coastal Region	Pre-monsoon (April-May) and Post-monsoon (October-November)	*Aman* and *Boro* rice damaged, farm-based wage labor declined, petty trade and fishing disrupted
Riverbank Erosion	River Basin	Monsoon (June-September) and Post-monsoon (October-November)	Cropland eroded
Landslide	Hill Tracts	Monsoon (June-September)	-

In tackling hazards or threats, communities use local knowledge which is referred to as indigenous knowledge, and the application aspect of it is termed as 'coping mechanism' or 'coping strategy' (Twigg, 2015). People acquire this knowledge because of living in a specific set of environments and they are updated as they experience new events and ways of dealing with them through experiments. This report documents some negative and positive coping strategies that communities practice to cope with a number of adversities. These are applied to minimize impacts of disaster, including averting loss of life and property, preventing disruption of services and social functioning as well as reducing physical and emotional distress. The strategies, as responses to risks, are diverse as well as context specific. However, the practices fall into four general categories (referred by John Twigg, 2015), (i) Economic or material, (ii) technological, (iii) social or organizational, and (iv) cultural.

(i) Economic or Material Strategies

Economic strategies primarily focus on economic diversification in conjunction with local knowledge so that communities can fall back on numerous sources of income in the time of crisis or even on the business-as-usual situation to support their livelihoods. This report categorizes economic and material strategies between negative and positive coping strategies. Some of the negative coping strategies include *borrowing money from a relative or neighbor, taking a loan from moneylenders or NGOs with high* *interest*, *reducing the amount of food intake*, and *taking food of poorer quality*. Furthermore, *selling a household or productive asset, stopping child education, selling advanced labor, migrating to other areas* are also demonstrations of negative coping practices in the areas where communities are recurrently affected by hazards such as floods, flash floods, cyclones and storms, riverbank erosion, and landslide.

In terms of positive coping mechanisms, this report found out some common plus unique local practices, the most common practice is *crop diversification* which increases the chance of survival for some crops during hazards and environmental stress. The potentially exposed households also *practice duck and chicken rearing* so that they can sell or consume them during crisis periods. Moreover, vulnerable households also try to *store up a 'buffer' of food, grain, livestock, and cash* that they can draw on in difficult times. In addition, they have developed a variety of techniques for *preserving crops, fish, and vegetables by storing, salting, and drying*. When disaster strikes, it causes a shift or complete damage to the livelihood of the people. For livelihood coping strategies, sometimes they permanently *change their present income source or transform their livelihood sources*. For instance, the fish farmers of the Satkhira district of Bangladesh produce sweet water fish earlier which has changed now because of salinity intrusion into shrimp's cultivation.

(ii) Technological Strategies

Technological strategies include bringing changes to the infrastructure of households through innovative use of building materials and construction methods. These strategies indicate the fixed assets management including land management, building materials, and construction methods as well as some technical knowledge for protection during disasters (Twigg, 2015). This report found that *people who live in exposed zones and face drinking water crises use plastic sheets to collect rainwater*, *apply raw turmeric to water containers to preserve rainwater*, and *preserve water with fitkiri (alum)*. People from monsoon floods and cyclone-prone zones *use soap (i.e., lifebuoy) at the corner of the house*, *burn dried pepper and dhup*, *plant cactus (locally called fonimonsha)*, *spread the net around the house for getting rid of venomous snakes*. During and after a disaster, it is tough to get access to health care, people from disaster-prone areas have some local treatment practices for crises. They *apply turmeric and neem paste to treat scabies and other dermatological problem*. For children or infants, they *mix turmeric with breast milk to treat common colds*, *use lime and mustered oil mix for treatment of bad cough*. One of the most important hygiene practices which often overlooked in developing countries is menstrual hygiene. Women and adolescent girls *use soft cloths, tissue paper, and sometimes wet cloths during stressful moments as very few get access to hygiene kits and sanitary napkins*.

(iii) Social Strategies

Social strategies include making use of kinship networks, mutual aid and self-help groups, and community-based organizations to cope with disasters. One of the fundamental units for reducing risk is family and during the time of stress, relatives outside of the affected community become significantly important. This study reveals that in terms of social strategies assistance can come in the form of *sharing food, labor, or other forms of mutual support*. Furthermore, the family can *help an individual to* *cope with trauma after a disastrous event*. They *apply mosques' mike for social communication during crisis moments*. Ensuring the protection of women and adolescents, they *keep them in a separate place in a shelter or send them to their relatives outside*. Some communities *establish a youth volunteer team for protection*.

(iv) Cultural Strategies

Cultural strategies encompass perception of risk and their religious views since it influences how they react and respond to disastrous events. Locally, people often make disaster forecasts by looking at the color of river water, movement of clouds, wind direction, and the behavior of animals. This report found that the flood-prone communities in Bangladesh *apply local knowledge such as heavy rain in Ashar-Shraban (June and July), heavy rain in Bhadra-Ashwin (August and September), rapid cloud movement from west to east, river watercolor turning muddy as flood forecasting as well as riverbank erosion signs*. It helps the community to evacuate and harvest their crops on time.

Additionally, for cyclone forecasting, *they use indigenous knowledge such as strong wind blowing from north to south in Chaitra-Baisakh (March and April), warm wind blowing, abnormal behavior of fishes in the sea, ants, and other insects carrying foods at higher places*. Sometimes red cloud in the sky warns them of hailstorms. For riverbank erosion, they *follow river currents and winds, when the wind blows from north to south in Jyastha (May) and recurring visits of river seagulls in Poush-Magh (December and January)*, they forecast it as signs of upcoming riverbank erosion.

5. THRESHOLD AND TRIGGER ANALYSIS

5.1. Overview

Bangladesh has a tropical monsoon climate characterized by seasonal variation in rainfall and wind pattern. During nouthwest monsoon (rainy season) i.e. July-September, Bangladesh receives heavy rain, whereas cool and dry weather prevails during northeast monsoon (winter season) i.e. December-February. In between those seasons, during March-May the country is susceptible to severe thunderstorms, locally called nor'wester season. Tropical cyclones form over the Bay of Bengal and hit Bangladesh during the pre-monsoon (April-May) and post-monsoon (October-November) seasons. There are also other cascading hazards related to monsoons such as landslides in Chattogram and Chattogram hill-tract and riverbank erosion at the Jamuna, Ganges, and Padma Rivers.

Bangladesh has been able to make noteworthy progression in developing strong early warning mechanisms for the two most common disasters- flood and cyclone that have a devastating impact on vulnerable communities of the country. However, for disasters such as landslides and riverbank erosion which have been recurring over the last few years, similar mechanisms of providing early warnings are yet to be developed.

The ministries and executive agencies involved in the Early Warning System in Bangladesh are below:

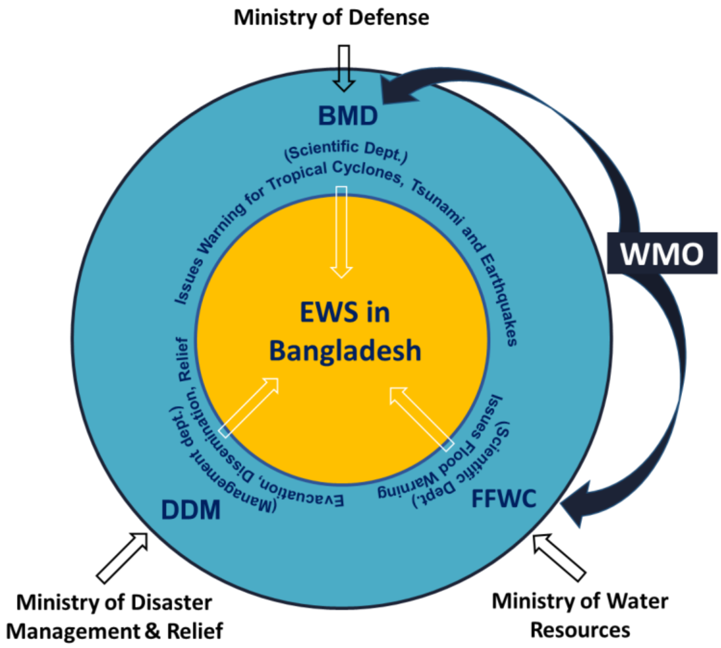


Figure 5.1: Ministries and executive agency involved in early warning system in Bangladesh

5.2. Impact Based Forecast

Impact-based forecasts aim to turn forecasts and warnings from descriptions of 'what the weather will be' into assessments of 'what the weather will do'. Impact-based forecasting drives actions that save lives and protect property and livelihoods. It triggers anticipatory actions/forecast-based financing mechanisms. There can be several forms and scales of the impact-based forecast, but all will require a co-design and co-production process to make the forecast products actionable.

The World Meteorological Organization (WMO), established a road map that identifies the various milestones from weather forecasts and warnings to multi-hazard impact-based forecast and warning services, advocating for a strong partnership between National Meteorological and Hydrological Service (NMHS) and Risk Reduction and Response Service (RRRS) agencies. It recommends an operational approach to identify how the likelihood of an expected hazard and its potential severity can be considered in tandem to create a risk matrix. Figure 5.2 illustrates a suggested operational application of the impact warning concept, combining impact with likelihood to create a risk matrix, expressing risk through a simple "traffic-light" color scheme. It is to be recalled here that impact incorporates an assessment of vulnerability and exposure.

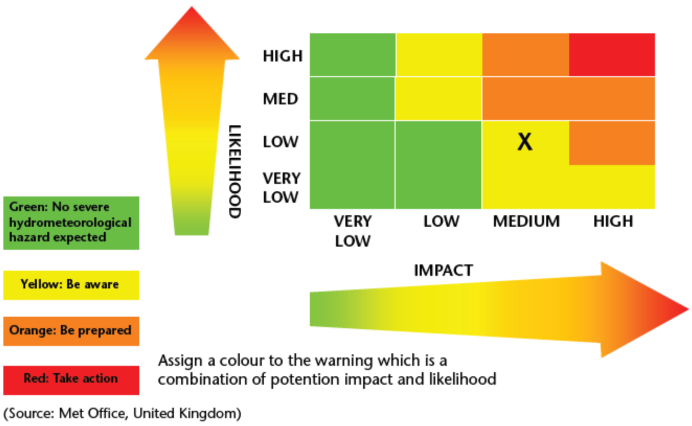


Figure 5.2: Risk matrix graph

5.3. Flood Forecast and Trigger

Flood Forecasting and Warning Centre (FFWC) generates and provides flood forecast and warning information based on scientific principles, real-time data, weather forecast information, and mathematical models. Based on its findings, FFWC disseminates information about the water level in absolute terms as well in references to the danger level and flood prediction. There are four main observation stations in Bangladesh: the Bhairab Bridge, Bahadurabad, Hardinge Bridge and Aricha are representing the Meghna, Brahmaputra-Jamuna, Ganges, and Padma rivers respectively. These four river systems are the major sources of flooding in Bangladesh. Except the Bhairab bridge, other stations measure the water level at the entry point of the basin. The Bahadurabad hydrological station of Bangladesh Water Development Board (BWDB) is in the upstream boundary of the Jamuna river and maintains long observation records of water levels, discharge, and flooding in the Brahmaputra-Jamuna basin. Hence, the Bahadurabad station has been always considered and used as a threshold to represent the Brahmaputra-Jamuna basin flooding and starting point to predict flood impacts.

On the other hand, Bangladesh faces another type of flood, called the ‘flash flood’, when continuous rain falls over hilly areas within a short duration causing surface water runoff or mudflows. Bangladesh Metrological Department (BMD) weather radars now observe such rainfall over the hills which can trigger flash floods. The FFWC issues five days’ deterministic forecast that indicates the water level in reference to the predetermined danger level. Also, the FFWC produces a medium-range (1-10 days) probabilistic forecast.

The Global Flood Awareness System (GloFAS) is produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) as part of the Copernicus Emergency Management Service (CEMS) that provides operational extended-range ensemble flood forecasts with a 30-day lead-time for major world river basins including the Brahmaputra in Bangladesh (Alfieri et al., 2013). The GloFAS team from the University of Reading and ECMWF are working together with the Bangladesh Flood Forecasting and Warning Centre (FFWC) and humanitarian partners to improve flood early warning in Bangladesh so that issued forecasts to the government and stakeholders are as skillful and useful as possible. GloFAS is freely available through a dedicated web interface (https://www.globalfloods.eu/). The type of flood that happens can vary significantly depending on the monsoon rainfall and basin hydrological characteristics. GLoFAS flood forecasters consider three very important questions: when will flooding commence during the monsoon period, how long it will last, and will there only be one flood wave or many flood waves? The flood impact for Bangladesh combines the 2-, 5- and 20-year exceedance probabilities into category-based information. It shows where the ENS-max (maximum of the ensemble mean discharge) for forecast days 11-30 is >20 year (purple) / 5-20 year (red) / 2-5 year (dark yellow). Light yellow indicates where the ENS-max is below the 2-year return period value. The probability is considered 0-100 for 5 years and 20 years return period.

For better understanding the impact-based forecast, the following risk matrix considers the GLoFAS and FFWC forecast information:

LIKELIHOOD (5 years and 20 Years)	**HIGH**	>70%				
	MEDIUM	50%-70%				
	LOW	30%-50%			**X**	
	VERY LOW	>30%				
Risk Seriousness			<2 Years (70,000 to 75,000 m'3)	2-5 Years (75,000 to 90,000 m'3)	5-20 Years (90,000 to 105,000 m'3)	>20 Years (>105,000 m'3)
			VERY LOW (MINIMAL)	**LOW (MINOR)**	**MEDIUM (SIGNIFICANT)**	**HIGH (SEVERE)**
			IMPACT (at Bahadurabad Station)			

Table 5.1: Risk matrix for flood

Based on the above risk matrix and continuous monitoring of GLoFAS and FFWC forecast from June to September, an agency could determine its own trigger model for anticipatory actions in monsoon floods.

Central Emergency Response Fund Monsoon Flood Trigger Model in 2021

The model makes use of available forecasts with a two-step trigger system to predict severe monsoon floods in Bangladesh:

- **Stage I:** Readiness trigger is reached when the water discharge at the Bahadurabad gauging station over a period of three consecutive days is forecasted by the GloFAS model with a maximum 15-day lead time to be more than 50% likely to cross the 1-in-5-year return period.
- **Stage II:** Action trigger is reached when the water level at Bahadurabad is forecasted by the FFWC 5-day lead time model to cross the government-defined "Danger Level" + 0.85 meters, and probabilistic forecasts with longer lead times (GloFAS/RIMES) show a sustained or increasing trend of the water discharge at the Bahadurabad gauging station for at least three consecutive days beginning from the day when the danger level is forecast to be crossed.

5.4. Cyclone Forecast and Trigger

The Bay of Bengal has a double peak of cyclone activity: one in April and May, the so-called pre-monsoon season, and another in October and November, the post-monsoon season. Cyclone is referred to as making landfall when its center, not its edge, gets onshore after moving over the ocean. Near the center of a cyclone is where most of the damage occurs because damaging aspects, such as the core of strong winds, heavy flooding rains, and peak of storm surge, are concentrated under the area. However, before the landfall of the cyclone, stormy weather may already affect the coast and inland for hours; in fact, a cyclone can bring its strongest winds over land before making landfall.

The storms receive cyclone names once the maximum average wind speed exceeds 62 km/hour. Cyclones are officially categorized into several ranks according to maximum wind strength. Bangladesh Meteorological Department (BMD) has an elaborate network of surface and upper air observatories, radar and satellite stations, and meteorological telecommunication system. Through this system, they detect and constantly monitor cyclones from formation and amplification in the Bay of Bengal until landfall and issue cyclone warnings.

Category	Wind Speed (Maximum Average)
Super Cyclone	≥220 km/h
Severe Cyclonic Storm With a core of Hurricane wind	118-219 km/h
Severe Cyclonic Strom	89-117 km/h
Cyclonic Strom	62-88 km/h
Deep Depression	51-61 km/h
Depression	41-50 km/h
Well-marked Low	31-40 km/h
Low	17-30 km/h

Table 5.2: Wind speed for cyclone

The center of a cyclone is called the "eye" and wind speed in the eye is different than wind speed impact to the community. The cyclone signal uses different wind speed calculations for community impact by the cyclone. The system uses 11 types of signals; signal number 1-10 indicates the magnitude, position, and direction of the upcoming cyclone and signal number 11 indicates that all communications with the Storm Warning Centre have broken down. BMD broadcasts distance and local cautionary signals and danger and great danger signals. It uses national television and radio and its website to disseminate this information; as well it directly communicates with other relevant actors as listed in the

Standing Orders on Disaster (SOD) through telephone, tele-printer, telegram, fax, and email. Information disseminated by Bangladesh Meteorological Department mainly denote the current location of the cyclone in reference to Mongla, Payra, and Chattogram ports, intensity, and trajectory of the cyclone, and likely time and place of its landfall.

As a follow-through of Danger Signal or Great Danger Signal issued by the Bangladesh Meteorological Department, district and upazila authorities mobilize all resources under their disposal – e.g. Police, Ansar and Cyclone Preparedness Programme (CPP) volunteers, and send them to every part of the communities to advise people through megaphones to move to safe shelters. NGOs' field staff also participate in this effort. It is also supported by mobile phone SMS as well as local efforts including public announcement system through mosques.

In addition, they hoist flags that denote cyclone warnings in the localities. The purpose of this message is to inform people about impending cyclones and to initiate evacuation to save lives. Therefore, along with information dissemination, the Local Administration embark upon evacuating people to safe places.

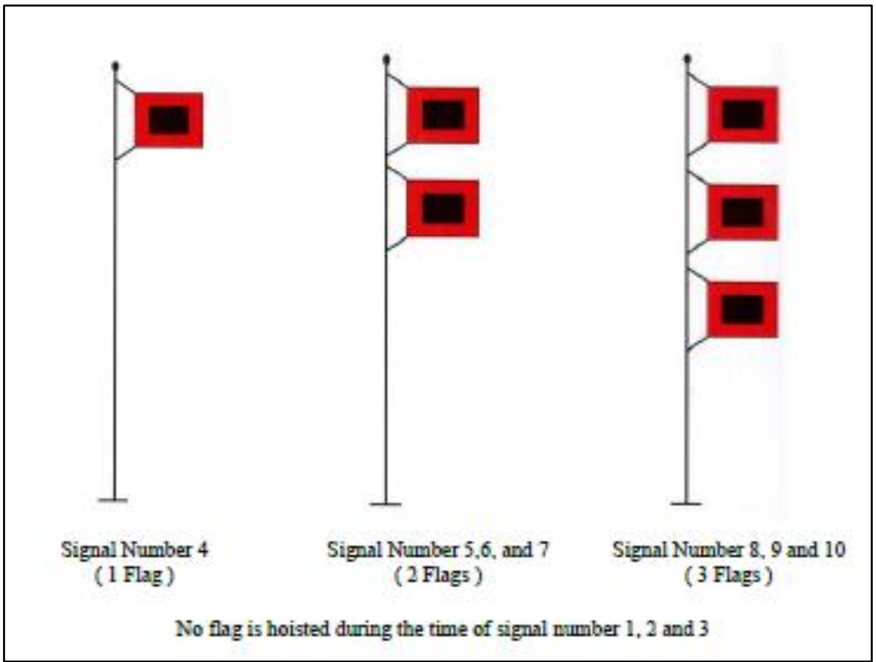


Figure 5.3: Flag's hoist to inform community for taking precautions in

The Global Disaster Alert and Coordination System (GDACS) was created as a cooperation framework between the United Nations and the European Commission in 2004, in order to address significant gaps in information collection and analysis in the early phase of major sudden-onset disasters. For the past decade, GDACS has drawn on the collective capacity of disaster managers and information systems worldwide to facilitate international information exchange and decision-making. GDACS Disaster Alerts are issued and disseminated to some 25,000 subscribers immediately following sudden-onset disasters. The automatic estimates and risk analysis – the basis of the alerts - are provided by the European Commission Joint Research Centre (JRC) and the Global Flood Observatory. Tropical Cyclones constitute a major threat to a number of highly vulnerable countries in the north-eastern and western Pacific, western Atlantic, and the Indian Ocean. The principal cyclone posed by them and considered by GDACS are strong winds, heavy rainfall, and storm surge (coastal flooding by an increase of the sea level due to strong winds and low pressure). The tropical cyclones GDACS alerts can serve also as an early warning tool, as they can be issued before the event affects the population. GDACS receives regular bulletins from meteorological organizations, covering all tropical cyclone basins, every six hours. These bulletins provide the current and forecast position and wind speeds of active tropical cyclones from the moment they are formed until they are dissolved. The forecasts can extend up to five days in the future. The risk for each of the abovementioned hazards is then calculated:

- For winds, GDACS calculates how many people live in the area that will be affected by winds of Tropical Storm force or stronger in the period covered by the latest forecast. Stronger winds, higher population - or a high percentage of the whole country's population - and higher vulnerability result in a higher alert level. As an example, winds stronger than 120 km/h (the threshold of Hurricane or Typhoon strength) that are predicted to affect more than 1 million people in a highly vulnerable country will trigger a red alert.
- For heavy rainfall, GDACS considers the tropical cyclone special rainfall forecast by NOAA. A predicted total accumulation over land (for the whole life cycle of the cyclone) of more than 500 mm or a maximum rain rate of more than 33 mm per hour will result in a red alert for rain.
- For the storm surge, GDACS uses estimates by JRC-developed code that calculates the storm surge at each point of the coast that is forecast to be near the tropical cyclone's path. These calculations are updated as soon as a new bulletin is received, so the numbers of the predicted storm surge height could change every 6 or 12 hours. A water height of more than 1 m above the astronomical tide in the vicinity of a populated coastal area will trigger an orange alert, more than 3 m - a red alert.

For better understanding the impact-based forecast, the following risk matrix considers the GDACS and BMD forecast information considering the likelihood of winds speed and storm surge corresponding to impact the population.

LIKELIHOOD	**HIGH**	>89 km/h maximum sustain wind speed (Signal 8,9,10) >3 m surge height				
	MEDIUM	62-88 km/h maximum sustain wind speed (Signal 5,6,7) 2-3 m surge height				
	LOW	51-61 km/h maximum sustain wind speed (Signal 4) 1-2 m surge height			**X**	
	VERY LOW	<50 km/h maximum sustain wind speed (Signal 1, 2, 3) up to 1 m surge height				
Risk Seriousness			500,000 Pop	1,000,000 Pop	1,500,000 Pop	2,000,000 Pop
			VERY LOW (MINIMAL)	**LOW (MINOR)**	**MEDIUM (SIGNIFICANT)**	**HIGH (SEVERE)**
			IMPACT (The cyclone landfall district plus other two adjacent districts)			

Table 5.3: Risk matrix for cyclone and storm surge

Based on the above risk matrix and continuous monitoring of GDACS and BMD forecast, an agency could determine its own trigger model for anticipatory actions in cyclone and storm surge.

RCRC Movement Disaster Relief Emergency Fund (DREF) Cyclone Trigger Model in Bangladesh

The model considers the 30 hours lead time for cyclones; The trigger based on forecast provided by BMD and IMD along with global forecast models. The trigger will be activated when BMD issues a forecast of a cyclone making landfall in Bangladesh with wind speeds greater than 125 km/h. This corresponds to a return period of approximately 1 in 5 years (this is an average over time; it is even possible to have more than one trigger in given year).

The revised Standing Order on Disaster (SOD) 2019 provides guidance for impact and community actions based on the wind speeds.

Table 5.4: Guidance for impact and community actions based on the wind speeds in SOD 2019

Signals	Wind (km/h)	Flag	Probable Effects/Impacts	Messages for the community
Signal 8,9,10	>89 km/h	Three	▪ Areas within the warning area may experience severe negative impacts. ▪ Uncounted coconut and other big trees may be destroyed or uprooted. ▪ Standing crops may be fully damaged. ▪ All the kacha and semi-pucca houses may be severely damaged. ▪ Light to moderate brick structures may also be significantly affected. ▪ Electricity supply and communications may be heavily disrupted. ▪ Selected areas and their low-lying areas may be flooded with …ft height tide.	▪ Evacuation of all people to safe buildings and cyclone shelters within the area should be completed. ▪ Keep an eye on the main areas which will/may be hit first and stay in safe shelters until the severe storms end. ▪ The first responding institutions should have full preparedness for emergencies and wait until further notice from the EOC.
Signal 5,6,7	62-88 km/h	Two	▪ Many coconut trees may be broken and destroyed. ▪ Many big trees may be uprooted. ▪ Crops may be severely damaged. ▪ Roofs of most of the kacha and semi-pucca houses may be blown away or damaged. ▪ Electricity supply and communications may be disrupted. ▪ Selected areas and their low-lying areas may be flooded with …ft height tide.	▪ People within the warning area may take shelter in pucca buildings or cyclone shelters. People should stay away from the sea or riverbank. ▪ Keep eyes on the main areas which will/may be hit first and stay in safe shelters until the severe storm end. ▪ The first responding institutions should come forward to help people, especially women, children, the elderly and persons with disabilities and wait until further notice from the EOC.
Signal 4	51-61 km/h	One	▪ Some coconut trees may be broken and some of the big trees may be uprooted. ▪ Crop fields may be severely damaged. ▪ Kacha and semi-pucca houses may be partially or fully damaged. ▪ Selected areas and their low-lying areas may experience low to moderate tide.	▪ Keep valuable items in a safe place. ▪ Prohibit children from playing outside. Listen to the announcement of the Ministry of Disaster Management & Relief and special bulletins disseminated by cyclone volunteer groups. ▪ Government and non-government agencies should take initiatives ▪ to make people aware and wait for the next instructions from the emergency control centre.
Signal 1, 2, 3	<50 km/h	No	▪ Branches of small trees may be broken. ▪ Roofs of light houses may be blown away or damaged. ▪ May damage the crops if the depression gains power and crosses the coast.	▪ Be Prepared - a cyclone has formed. ▪ Act as per Community Cyclone Preparedness Plan. ▪ Prepare battery-run radios and torch lights.

				▪ Listen to Radio and TV or dial 1090 on mobile phone for the latest cyclone news. ▪ Store dry food, potable water, emergency medications and first aid materials.

5.5. Landslide Forecast and Trigger

The early warning system uses thresholds for soil moisture and water supply from rain to issue warnings to the public and relevant authorities when the risk for landslide hazard is present. Debris flow early warning has always been based on well-calibrated rainfall thresholds. In Bangladesh, there is no landslide warning system, but Bangladesh Metrological Department (BMD) is mandated to monitor, analyse and predict all climate and meteorological phenomena including rainfall. The BMD expresses the rain intensity and forecasts rain area as below.

Table 5.5: Rain intensity	
Light Rain	<10 mm/day
Moderate Rain	11-22 mm/day
Moderately Heavy Rain	23-43 mm/day
Heavy Rain	44-88 mm/day
Very Heavy Rain	>88 mm/day

Table 5.6: Forecast rain area	
One or two places	Up to 25% of total area
Few places	26-50% of total area
Many Places	51-75% of total area
Most Places	More than 75% of total area

The Bangladesh University of Engineering and Technology-Japan Institute of Disaster Prevention and Urban Safety (BUET-JIDPUS) took the initiative in 2014 to develop an information system that can provide landslide early warning alerts to vulnerable communities. Following are the recommendations that emerged from the precipitation threshold value for Cox's Bazar and Teknaf municipalities. Recommended threshold values with a corresponding alert system were developed for the target communities.

For better understanding the impact-based forecast, the following risk matrix considers the GLoFAS (10 days forecast) and BMD (seasonal/24 hours forecast) forecast information considering the likelihood of rain intensity corresponding to impact forecast rain area in the most vulnerable landslide-prone site.

LIKELIHOOD	HIGH	>300 mm rain within 10 days (40% probability)				
	MEDIUM	>150 mm rain within 10 days (60% probability)				
	LOW	>50 mm rain within 10 days (80% probability)			X	
	VERY LOW	<50 mm rain within 10 days				
Risk Seriousness			0-20% area	20-40% area	40-60% area	>60% area
			VERY LOW (MINIMAL)	LOW (MINOR)	MEDIUM (SIGNIFICANT)	HIGH (SEVERE)
			IMPACT (Most vulnerable landslide site)			

Table 5.7: Risk matrix for landslide

Based on the above risk matrix and continuous monitoring of GDACS and BMD forecast, an agency could determine its own trigger model for anticipatory actions in landslide.

5.6. Riverbank Erosion Forecast and Trigger

Center for Environmental and Geographic Information Services (CEGIS) has been predicting riverbank erosion for the last 16 years along the Jamuna, the Ganges, and the Padma Rivers. Prediction activities were funded by the Jamuna-Meghna River Erosion Mitigation Project (JMREMP) and EMIN of BWDB has funded the erosion prediction efforts in the last ten years under financial assistance from the Asian Development Bank (ADB) and the Government of Netherlands. CEGIS is predicting riverbank erosion in the major rivers one year ahead. Additionally, they have developed tools for predicting two-year advanced riverbank erosion for the Jamuna, the Ganges, and the Padma Rivers separately. Evaluation of the predictions for the last few years shows a reasonably good match with the occurrences.

Riverbank erosion prediction can be conducted through different approaches. The commonly exercised methods are: i) physical modeling, ii) numerical modeling and ii) empirical modeling. CEGIS has updated the existing prediction tools for the Jamuna, Padma and Ganges rivers by analyzing good-quality long-time series images and by categorizing particular shapes of sedimentary features. Over the past several years, these methods of predicting morphological changes and bank erosion were successfully applied in a number of BWDB and WARPO projects. The erosion vulnerability assessment represents in the range of 30%, 50% and 70% probability.

For better understanding the impact-based forecast, the following risk matrix considers the CEGIS and FFWC forecast information about the impact on erosion vulnerable settlements and the likelihoods of erosion.

LIKELIHOOD	HIGH	70% vulnerable to erosion	X			
	MEDIUM	50% vulnerable to erosion			X	
	LOW	30% vulnerable to erosion				
	VERY LOW	<30% vulnerable to erosion				
Risk Seriousness			1-10 Ha settlements	10-20 Ha settlements	20-30 Ha settlements	>30 Ha settlements
			VERY LOW (MINIMAL)	LOW (MINOR)	MEDIUM (SIGNIFICANT)	HIGH (SEVERE)
			IMPACT (Riverbank erosion in each district)			

Table 5.8: Risk matrix for riverbank erosion

Based on the above risk matrix and continuous monitoring of CEGIS and FFWC forecast, an agency could determine its own trigger model for anticipatory actions in riverbank erosion.

6. WAY FORWARD

This study has used data from different reliable government, non-government, and global sources to guide evidence-based decision making, primarily focusing on seven years extending from 2014 to 2020, and verified the findings with long-term datasets such as the EM-DAT. The data, framework, and results from this assignment will augment improved decision-making of relevant agencies such as MoDMR, Start Fund Bangladesh, UN agencies, etc. before, during, and after a crisis event rather than only relying on poverty-related data. However, there are areas for improvement, for example, sub-national level hazard modeling including climate change scenarios to project future likely impacts could guide better planning. Moreover, the Household Economy Analysis (HEA) could assist further understanding of the severity of needs for improved targeting of people. Although INFORM risk index has been done recently by NIRAPAD with the assistance of MoDMR, DDM, CARE Bangladesh, and other relevant agencies for three districts at the subnational level as piloting, a countrywide INFORM risk index could be brilliant addition towards a better understanding and improved decision making for Bangladesh given the dearth of data-centric decision-making availability of tools and methodologies.

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