Project Report: 2013-35

Assessment of Capabilities, Needs of Communities, Opportunities and Limitations of Weather Forecasting for Coastal Regions of Bangladesh

CLIMATE CHANGE AGRICULTURE AND FOOD SECURITY

CGIAR
RESEARCH PROGRAM ON
Aquatic Agricultural Systems

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Assessment of Capabilities, Needs of Communities, Opportunities and Limitations of Weather Forecasting for Coastal Regions of Bangladesh

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Abbreviations and acronyms

BARC	Bangladesh Agriculture Research Council
BIWTA	Bangladesh Inland Water Transport Authority
BMD	Bangladesh Meteorological Department
BRTC	Bureau of Research, Testing and Consultation
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CCAFS	Climate Change, Agriculture and Food Security
CEGIS	Center for Environment & Geographic Information Services
CPP	Cyclone Preparedness Programme
DAE	Department of Agricultural Extension
DoE	Department of Environment
DMB	Disaster Management Bureau
DPHE	Department of Public Health Engineering
FFWC	Flood Forecasting and Warning Center
IWFM	Institute of Water and Flood Management
IWM	Institute of Water Modeling
JMA	Japan Meteorological Agency
LGED	Local Government Engineering Department
NASA	National Aeronautics and Space Administration
NGO	Non-Government Organization
PTWC	Pacific Tsunami Warning Center
PWD	Public Works Department
RHD	Roads and Highways Department
SWC	Storm Warning Centre (Dhaka)
WMO	World Meteorological Organization

Chapter one: Long- and medium-term weather prediction systems

1.1 Introduction

Bangladesh is highly vulnerable to a range of potential natural disasters due to its: i) unique geographic situation—80% of the country's 140,000 km2 are effectively floodplains of major river systems (Hopson and Webster, 2010) and much of the country is less than10 meters above sea level; ii) very high annual levels of rainfall—mean annual rainfall is approximately 2300 mm (World Bank 2012a); iii) high density of human population (approximately 150 million inhabitants); iv) high population density and growth of density—1142 people/km2 of land (World Bank 2012b); and v) poverty—GDP/capita for 2011 was US$735 (World Bank 2012b). This population is bolstered by influxes of migrant workers into southern Bangladesh that coincide with two storm seasons.

Given this inherent vulnerability in a number of areas, Bangladesh also faces a number of different types of natural disasters. These are:

- Floods.
- Cyclones and associated storm surges.
- Thunderstorms/tornadoes/hailstorms.
- Drought.
- Heat waves/cold waves.
- Land slides.

Exacerbating these issues are the risks associated with anthropogenic climate change, with potentially increased rates of flood and water inundation, with concomitant implications for human welfare and food production (Mirza et al. 2003). Projected increases in sea surface temperature (SST) in the Bay of Bengal (Rahman et al. 2011), the apparent historical relationship between SST and cyclone potential intensity (Kotal et al. 2008) and modeled responses of cyclonic storm surge flooding (Karim and Mimura, 2008), all indicate that cyclones may increase in frequency, intensity and on-ground impact in the future. The impacts of cyclones in Bangladesh can be little short of catastrophic—in 2007, Cyclone Sidr caused damage that accounted for 2.6% of GDP and resulted in over 3,000 fatalities and over 55,000 injuries (World Bank 2010). The impacts on agriculture in terms of lost production through storm-related crop damage are considerable (e.g. agricultural losses from Cyclone Sidr estimated at US$438 million—World Bank, 2010), and crop production losses are projected to increase due to climate change in the coming century (Yu et al. 2010). These threats, impacts and projections all require a significant on-ground response, such as increased shelter provision (Karim and Mimura, 2008), improved forecasting of cyclonic events (Paul and Routray, 2013) and adaptation of agricultural practices to changing prevailing conditions and extreme event severity and frequency (World Bank, 2010).

Accurate and real time forecasting can significantly reduce both human casualties and damage to properties caused by natural disasters. Weather forecasting can play a vital role in cyclonic and storm surge forecasting, flood forecasting, drought predictions, and heat wave and cold wave forecasting. Of particular importance and influence are flood events—Bangladesh experiences five different types of flood: i) normal monsoon flood during the monsoon season; ii) internal excess rainfall flood during the monsoon season; iii) flash flood during the pre-monsoon season occurring mainly in the north-east parts of the country; iv) tidal floods; and v) cyclonic storm surges during the pre-monsoon and post-monsoon. Impacts can be exacerbated by coincidence of cyclone and monsoon seasons (Khan, 2012). Figure 1.1 shows a typical map of different types of flood and river bank erosion-prone areas of Bangladesh. Coastal areas of Bangladesh are especially prone to cyclone and storm surges. Figure 1.2 shows typical storm surge risk areas of Bangladesh based on the information of cyclone occurrence over the last century.

This report is intended to provide a range of background material in relation to Bangladesh and weather event forecasting, forecast information dissemination, and the implications of weather events and forecasting for communities and their livelihoods. It identifies where institutional efforts and funds have been, and are presently being focused, and ultimately makes some recommendations about CCAFS and WorldFish potential involvement/investment in these areas. The main focus of the report includes:

i. An outline of the issues that communities in Bangladesh face in relation to weather events, and in particular vulnerability to extreme weather events such as cyclones and associated storm surges and flooding;
ii. An overview of the primary stakeholders in relation to weather forecasting in Bangladesh, historical and ongoing projects and a description of the different types of forecast, forecast software and forecast outputs at various jurisdictional levels;
iii. A description of the different approaches to forecast information dissemination, the role of government institutions, non-government organizations, the different levels of forecast warning and the limitations of these approaches;
iv. The findings of participatory research conducted with coastal communities in Bangladesh in relation to weather forecasting, storm warnings, vulnerability and disaster preparedness;
v. A summation of the main findings and a series of recommendations, particularly as they relate to potential investment in weather and storm forecasting in Bangladesh by CCAFS and WorldFish.

1.2 Stakeholders, and past and on-going projects

There are a number of international, national and local organizations working on weather forecasting and prediction in Bangladesh. With some exceptions, these are predominantly government-based organizations, representing various tiers of governance (e.g. national, local). This government focus is likely to reflect: i) the inherent complexity of meteorological data (and hence the need for highly qualified, expert staff); ii) the monetary cost of acquiring, maintaining and operating equipment and infrastructure associated with weather forecasting; iii) the high level (and hence expense) of computer power required for collecting, collating, analyzing and storing data; and iv) the complex communication networks associated with structured information release and dissemination. This is not an emphasis that is unique to Bangladesh, as in many countries (e.g. Meteorological Office in the UK, Bureau of Meteorology in Australia, Météo-France, Instituto Nacional de Meteorologia in Brazil) the primary provider of weather forecasting data is housed within a government department, or is a distinct government entity dedicated to weather forecasting and research. As such, this document focuses primarily on weather forecasting from a government perspective, with a more restricted analysis of the role of non-government organizations (NGOs) which reflects their smaller role in weather forecasting.

Given the high level of vulnerability to, and frequency of, extreme weather events (such as cyclones) in Bangladesh, the forecasting of such events and the effective dissemination of information has been a high priority for many years and has attracted considerable government investment (World Bank, 2010).

Flood forecasting in Bangladesh is a highly complex process, due in part to the many types of floods that can occur, the complex network of river systems that crisscross the country (Paudyal, 2002), the significant uncertainty regarding cyclone event severity, frequency and spatial location, and uncertainty regarding how climate change may alter these patterns both globally and in the Bangladesh region (MOHC, 2010).

Given the social and economic implications of flooding in Bangladesh, coupled with the recognition that flood forecasting can increase preparedness and mitigate losses and is highly cost-effective, the country has a long history of investment and innovation in forecasting. Chowdhury (2000) provides the following synopsis of flood forecasting in Bangladesh, up to the late 1990s:

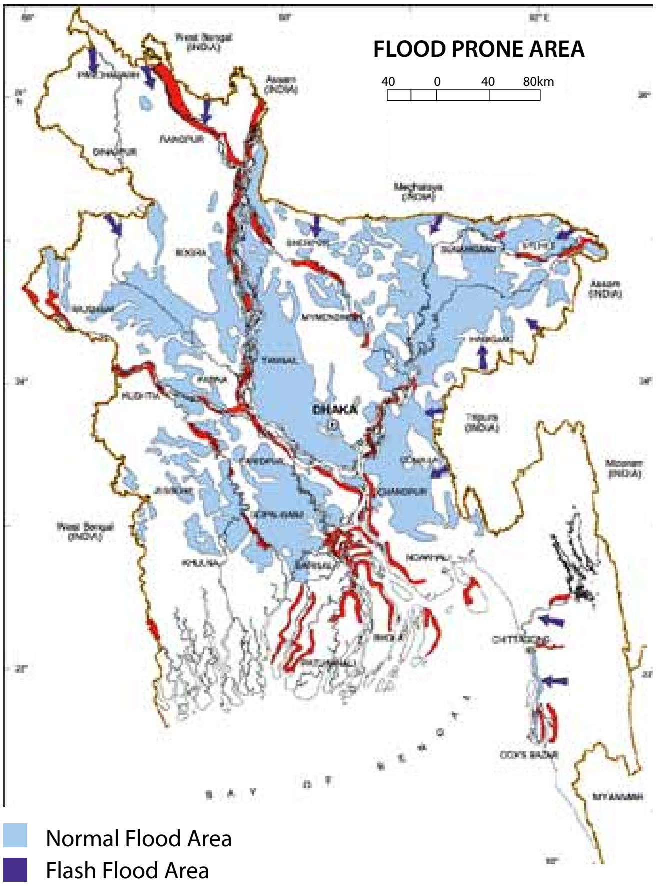
- To aid national preparedness for floods, in 1972, the Flood Forecasting and Warning Center (FFWC) was established under the administrative control of the Bangladesh Water Development Board (BWBD;
- Over time, the systems of forecasting were gradually and substantially improved;
- Following catastrophic floods in the late 1980s, flood control and forecasting became a major government imperative, leading to greater program investment;
- A national Flood Action Plan (FAP) was developed, addressing both structural and non-structural aspects of flood management (Chowdhury, 1998);
- As part of this approach, the Flood Forecasting and Early Warning system (FAP 10) was developed and implemented. This computer-based forecasting and warning system was used in the 1998 floods.

Traditionally, there has been a considerable reliance on satellite images for the tracking of cyclones in Bangladesh, with little recourse to supplementary data commonly used in many other countries from sources such as floating buoys, naval ships and aircraft carrying a wide range of meteorological sensors (Roy et al. 2006). However, in recent years, there has been a considerable research focus on improving cyclone and flood forecasting technology and capabilities in Bangladesh. Whilst a comprehensive overview of research and development in this area is beyond the scope of this report, some significant projects and developments include:

- The Climate Forecast Application in Bangladesh (CFAB) project was instigated in 2001, as a research and development consortium of various national (e.g. Department of Agricultural Extension, Ministry of Disaster Management and Relief) and international (e.g. Asian Disaster Preparedness Centre (Thailand), Georgia Institute of Technology (US)) organizations and institutes. The aims of the project covered a broad range of aspects of weather forecasting and response in Bangladesh, and included: i) develop short-, medium- and long-term forecasting approaches that are better able to predict weather events; ii) test/introduce Bayesian statistical methods to forecasting; iii) facilitate international partnerships and rapid data transfer; and iv) develop system improvements and technologies that can readily interface with existing systems in Bangladesh. The project was due for completion in 2004, but the most recent progress report on the project website (http://cfab.eas.gatech.edu/cfab/Documents/InfoSheets/CFAB_goals.pdf) is from 2003. This report indicates that good progress was being made with regard to predicative approaches, with predictive capacity improved. Tellingly, the technology used by the project to develop these improved predictions was already residing with a number of departments and institutions in Bangladesh. See the project website for further information: http://cfab.eas.gatech.edu/cfab/cfab.html .
- A review of approaches to flood management and mitigation in Bangladesh by Guna N. Paudyal (Paudyal, 2002) provides a succinct overview of developments in flood management up to the early 21st Century. These include: i) a realization that structural management of floods (e.g. earthworks, embankments) was very limited in its physical effectiveness and cost effectiveness, and hence a move towards information-technology-based solutions was initiated; ii) the subsequent development and implementation of a flood forecasting and warning system based on an advanced hydraulic model; iii) a realization that this system was limited to the main river systems (and therefore had little relevance to many potential end- users) and that dissemination was ineffective and rural uptake low; iv) the consequent development of a new flood forecasting system (MIKE11) that is linked to Geographic Information Systems (GIS) and includes depth-area inundation forecasts; and v) the coupling of MIKE11 with an improved dissemination system that includes a suite of phased warning messages—this system introduces early notification to other agencies, additional phases of warning messages as the severity and impact of flooding increases, warnings in many local dialects, and warning posts depicting flood depths being placed in community areas as an illustration of flood severity.
- The MIKE11 system continues to be upgraded and incrementally informed by current scientific developments and findings. The current premise of the MIKE11 system as applied to Bangladesh cyclone prediction is based on: i) the use of statistical models for predicting cyclone intensity and trajectory; ii) the use of a storm surge and spatially explicit flood modeling system; iii) a real time data assimilation system that can update cyclone track and intensity using surface observations of wind and pressure, and has a procedure for updating the storm surge model using water level measurements. The current MIKE11 system is MS Windows compatible, thus increasing its potential ubiquity. Further information on the system is available at the DHI website (http://mikebydhi.com/).
- There is an increased focus on technical improvements in weather data acquisition and analysis, coupled with increased sophistication and predictive power of models and heuristic testing of models (e.g. Basnayake et al. 2009 modeling nor`westers over Bangladesh). However, the power and accuracy of the models themselves, and even data availability and accuracy, may not be the limiting factors in model applicability and utility. Khan (2012) provides a number of insights into how models and forecasting systems do not sufficiently account for local physical, social and economic elements of a given community (e.g. gender differences, localized weather events, livelihoods). By addressing issues such as increasing interactions between local residents and climate modelers, more locally targeted weather forecasting approaches can potentially be developed (Khan, 2012).

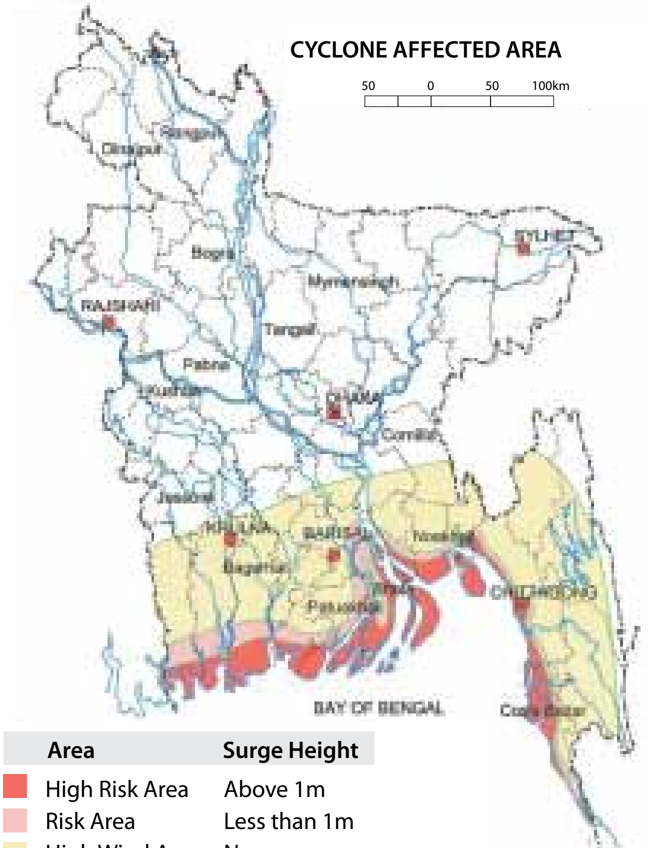
1.2.1 International

National organizations generate their weather forecasts using sources from a number of international organizations. The World Meteorological Organization (WMO) provides real-time data and information through the global telecommunications system to the Bangladesh Meteorological Department (BMD), and provides expertise and guidance materials to BMD and the Department of Hydrology.



Normal Flood Area
Flash Flood Area
Riverbank Erosion Prone Area

Figure 1.1. Type of flood and extent in Bangladesh.



Area	Surge Height
High Risk Area	Above 1m
Risk Area	Less than 1m
High Wind Area	None

Source: SPARRSO

Figure 1.2. Storm surge risk map for Bangladesh.

1.2.2. National

- Bangladesh Meteorological Department (BMD)
  BMD is the authorized Government organization for all meteorological activities in the country. It maintains a network of surface and upper air observatories, radar and satellite stations, agro- meteorological observatories, geomagnetic and seismological observatories and meteorological telecommunication systems. The Department has its Headquarters in Dhaka with two regional centers: the Storm Warning Center (SWC), Dhaka and the Meteorological & Geo-Physical Centre (M & GC), Chittagong.
- Flood Forecasting and Warning Center (FFWC)
  As stated in the BWDB Act 2000, flood forecasting in Bangladesh is the mandate and responsibility of the Bangladesh Water Development Board (BWDB). The Flood Forecasting and Warning Center (FFWC) of BWDB is fulfilling this responsibility. The FFWC of BWDB was established in 1972 and is fully operative in the flood season, from April to October every year, as directed by the Standing Orders for Disaster (SOD) of the Government of Bangladesh. The FFWC acts as the focal point in co-ordination with other ministries and agencies such as the Bangladesh Meteorological Department (BMD), Disaster Management Bureau (DMB), and the Department of Agricultural Extension (DAE) during the monsoon season, for flood disaster mitigation and management.

1.2.3 Local

There are a number of local committees responsible for receiving and disseminating cyclone warnings and working for disaster management:

- District Disaster Management Committee (DDMC) headed by the Deputy Commissioner (DC) to co-ordinate and review disaster management activities at the district level;
- Upazila Disaster Management Committee (UZDMC) headed by the Upazila Nirbahi Officer (UNO) to co-ordinate and review disaster management activities at the Upazila level;
- Union Disaster Management Committee (UDMC) headed by the Chairman of the Union Parishad to co-ordinate, review and implement disaster management activities of the concerned union;
- Pourashava Disaster Management Committee (PDMC) headed by Chairman of Pourashava (municipality) to co-ordinate, review and implement disaster management activities within its area of jurisdiction;
- City Corporation Disaster Management Committee (CCDMC) headed by the Mayor of City Corporations to co-ordinate, review and implement disaster management activities within its jurisdiction.

1.2.4 Access to information from researchers

A number of national research centers and academic institutions are also capable of providing useful information, forecasts and knowledge products prior to, during and after natural disasters:

- Institute of Water and Flood Management (IWFM) The Institute of Flood Control and Drainage Research established under Bangladesh University of Engineering and Technology (BUET) in 1974 was renamed the Institute of Water and Flood Management (IWFM) in 2002. The Institute pursues research and capacity development in the field of water and flood management that is vital for the economic development and social prosperity of the country. Recently, the Weather Research Forecasting (WRF) model has been successfully configured and now produces non-operational weather forecasts for the country. WRF is a next-generation meso-scale numerical weather prediction system, designed to serve both operational forecasting and atmospheric research needs. As an example of its capability, WRF has successfully simulated

cyclones in the Bay of Bengal and provides 5-day forecasting of weather.
- Institute of Water Modeling (IWM) The Institute of Water Modeling (IWM), a public trust organization, has been working, since 1990, with modeling software (known as MIKE) products, developed by Denis Hydraulics Institute (DHI). These models are used to compute flood elevation for flood forecasting and warning in Bangladesh. It also provides support on river modeling, to study river flow and floods, morphology, sediment transport, salinity, water quality, off-take dynamics etc. The modeling system also forms the basis for the assessment of environmental impacts—such as discharge of pollutants, dumping of spoils or land reclamation, salinity intrusion, cooling water discharge, floods and storm surges. IWM updates the recent development of water models around the world through Network with DHI as their regional associates. IWM shall provide the technical support to BMD, and BWDB (FFWC) will be the model development associate via the provision of necessary data and information.
- The Center for Environment & Geographic Information Services (CEGIS) CEGIS has extensive experience in the field of integrated environmental analysis, through the development of application models using input data and information from the available climate change and water models in Bangladesh. CEGIS has capabilities to transfer model forecasts to the local level using community-based information. CEGIS has also developed a Drought Assessment Application (DRAS) model in collaboration with Bangladesh Agriculture Research Council (BARC), for rapid assessment of the drought and its management guidelines for the country.

1.3 Types of forecasting

As mandated organizations, both BMD and FFWC of BWDB provide operational forecasting. The type of forecasts issued by these two organizations are listed below:

Forecast issued by BMD
- Daily district wise weather forecast.
- Weekly agro-meteorological forecasts.
- Long-range weather forecast for one month.
- Long-range forecast of three months for the Ministry of Agriculture, BARC, DAE and other related departments.
- Heavy rainfall warnings.
- Kalbaishakhi and other squall warnings.
- Cold- and heat-wave warnings.

Experimental weather forecasting maps by BMD
There are a number of experimental weather forecasting maps available on the BMD website (http://www.dmb.gov.bd/).

However, this information is only available as a map format for the following variables:
- WRF Experimental Forecast: 24, 48 and 72 hour rainfall.
- Non-Hydrostatic Model (NHM) Forecast: 12, 24, 36, 48, 60 and 72 hour rainfall, temperature, barometric pressure and wind composite map.
- Global Spectral Model (Japan Meteorological Agency) Forecast : 24, 48 and 72 hour forecast of rainfall, wind at 925 hPa, 850 hPa, 500 hPa, 300 hPa and 200 hPa.
- Storm surge height: 3 hourly surge map every 36 hours.

Forecast and output of FFWC, BWDB
- Daily monsoon bulletin & river situation report.
- River level forecasts for 24, 48 and 72 hours.
- Current warning messages.
- Special flood situation report.
- Thana inundation status map.
- Flood forecast maps.
- Monthly flood report.
- Dry season bulletin (weekly).
- Annual flood report.

1.3.1 Software

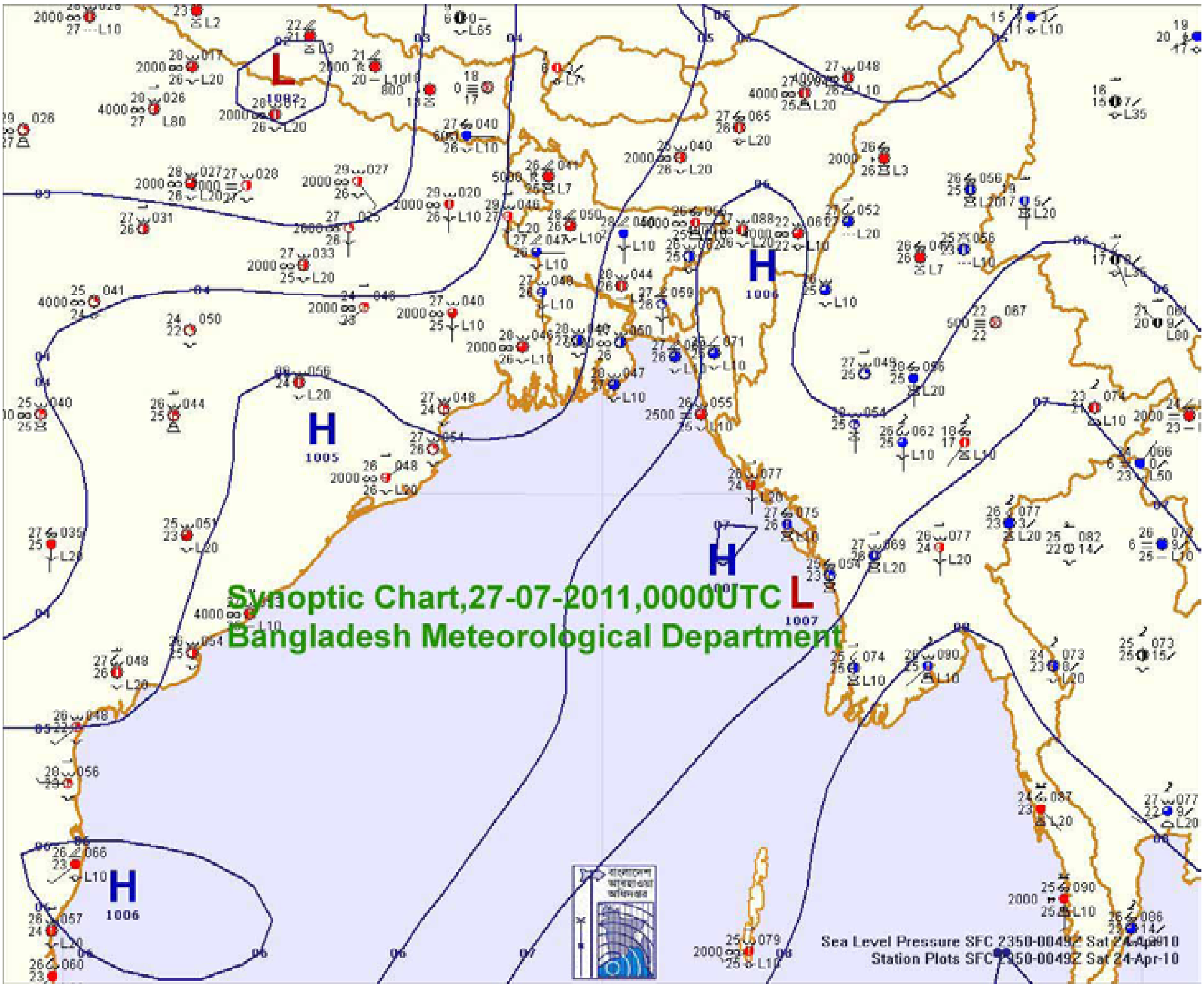
Numerical models used at Bangladesh Meteorological Department (BMD)

BMD provides experimental forecasts of weather for use in the following weather forecast models:
- Weather Research and Forecasting Experimental Forecast.
- Non-Hydrostatic Model (NHM) Experimental Forecast.
- Global Spectral Model (Japan Meteorological Agency) Forecast.
- Wave Model Products (Experimental).
- One Month Forecast.

Flood forecasting tools used at FFWC
One dimensional fully hydrodynamic model (MIKE 11 HD) incorporating all major rivers and floodplains are used for flood forecasting. This is linked to a lumped conceptual rainfall runoff model (MIKE 11 RR) which generates inflows from catchments within the country.

1.4 Geographical scale and coverage

Forecast from BMD
Daily weather forecast has been provided for all the meteorological stations and districts of Bangladesh. Figure 1.3 shows computer generated weather chart over Bangladesh.



International Weather Symbols

Numbers indicate the weather code as used in synoptic weather reports (ww, present weather reported from a manned weather station, as defined in WMO Pub. No. 306-A).

00 Cloud development not observed/observable during past hour.	01 Clouds generally dissolving during past hour.	02 State of sky unchanged during past hour.	03 Clouds generally forming or developing during past hour.	04 Visibility reduced by smoke.	05 Haze.	06 Dust suspended in the air, but not raised by wind.	07 Dust or sand raised by wind.	08 Dust devils now or within past hour.	09 Duststorm or sandstorm not at station but within sight.
10 Mist.	11 Patches of shallow fog at station, not deeper than 2 m (10 m at sea).	12 Continuous shallow fog at station, not deeper than 2 m (10 m at sea).	13 Lightning visible, but no thunder heard.	14 Precipitation visible but not reaching ground at station.	15 Precipitation reaching the ground not at or near the station but at a distance.	16 Precipitation reaching the ground not at the station but nearby.	17 Thunder heard but no precipitation at the station.	18 Wind squall now or during the past hour.	19 Tornado, waterspout, or funnel cloud observed now or during past hour.
20 Recent drizzle (not freezing, not showers) during past hour.	21 Recent rain (not freezing, not showers) during past hour.	22 Recent snow (not showers) during past hour.	23 Recent rain and snow (not showers) during past hour.	24 Freezing drizzle or rain (not showers), not now but during past hour.	25 Rain showers, not now but during past hour.	26 Snow showers, not now but during past hour.	27 Hail or hail and rain, not now but during past hour.	28 Fog, not now but during past hour.	29 Thunderstorm, with or without precipitation, not now but during past hour.
30 Slight/moderate duststorm or sandstorm, decreased during hour.	31 Slight/moderate duststorm or sandstorm, no change during hour.	32 Slight/moderate duststorm or sandstorm, increased during hour.	33 Severe duststorm or sandstorm, which has decreased during past hour.	34 Severe duststorm or sandstorm, no change during past hour.	35 Duststorm or sandstorm, severe, has increased during past hour.	36 Drifting snow, slight or moderate.	37 Drifting snow, heavy.	38 Blowing snow, slight or moderate.	39 Blowing snow, heavy.

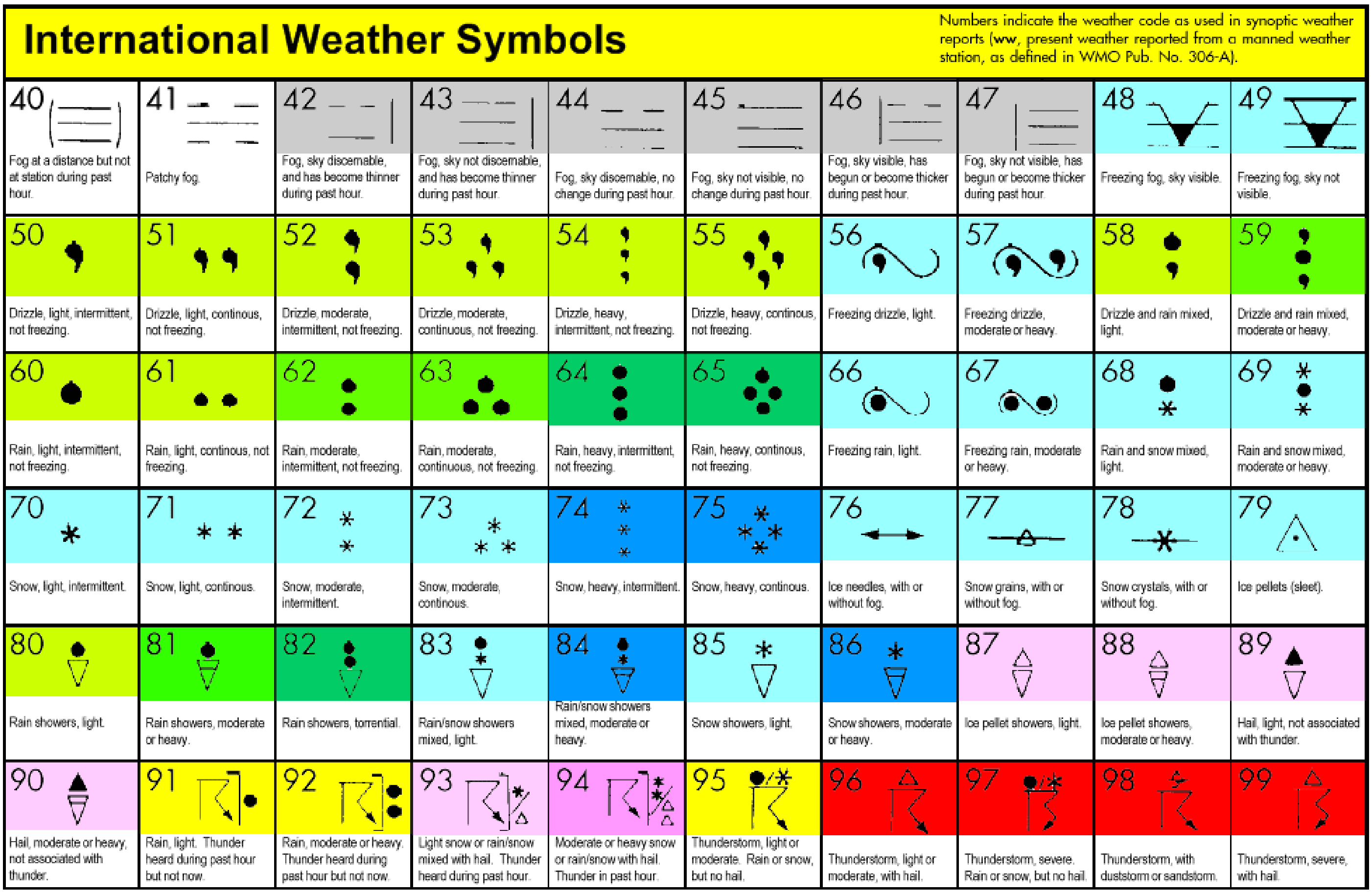
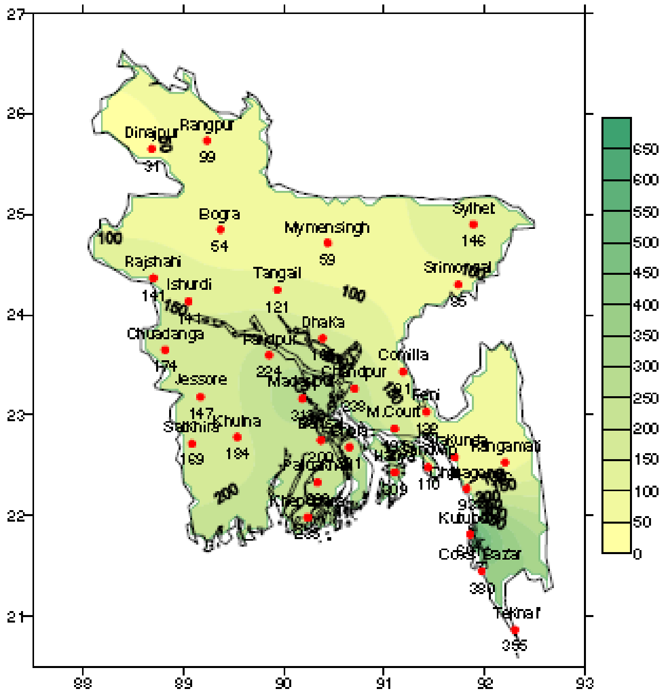


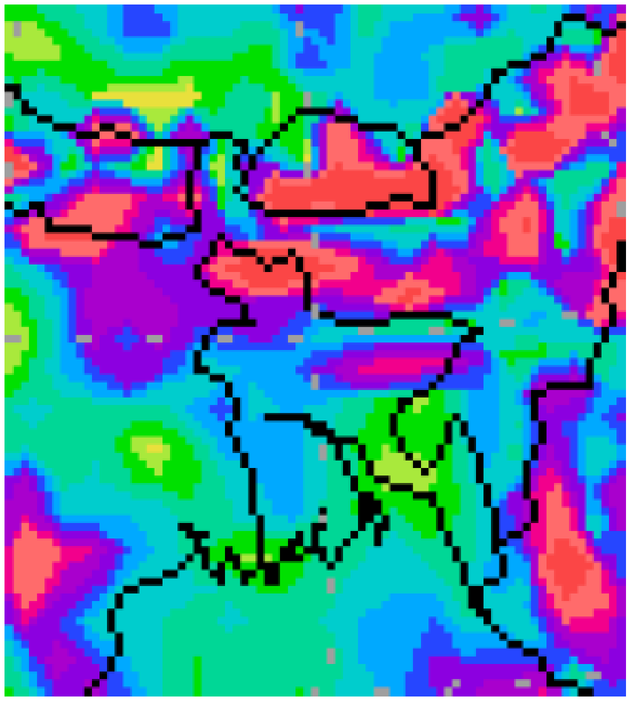
Figure 1.3. Computer-generated weather chart of Bangladesh (left) and standard symbols used on weather charts (right).

Weekly agro-meteorological information has been provided for Bangladesh. Figure 1.4 shows typical maps of rainfall distribution over Bangladesh. Information about temperature, rainfall, sunshine hours, wind speed, humidity and water stress have been provided for various zones (e.g. western, southern, central, northern, eastern) of Bangladesh. However, this information is not location-specific. This lack of specificity means that, even if the communication and dissemination of information is improved, the information is too general to be used as a means to prepare for certain weather events or take actions to mitigate potential damage.

Spatial distribution of Rainfall
(Period: 22-05-2013 to 31-05-2013)



Accumulative Rainfall forecast
(Period: 02-06-2013 to 07-06-2013)



Extended Outlook for accumulative rain
(Period: 08-06-2013 to 14-06-2013)

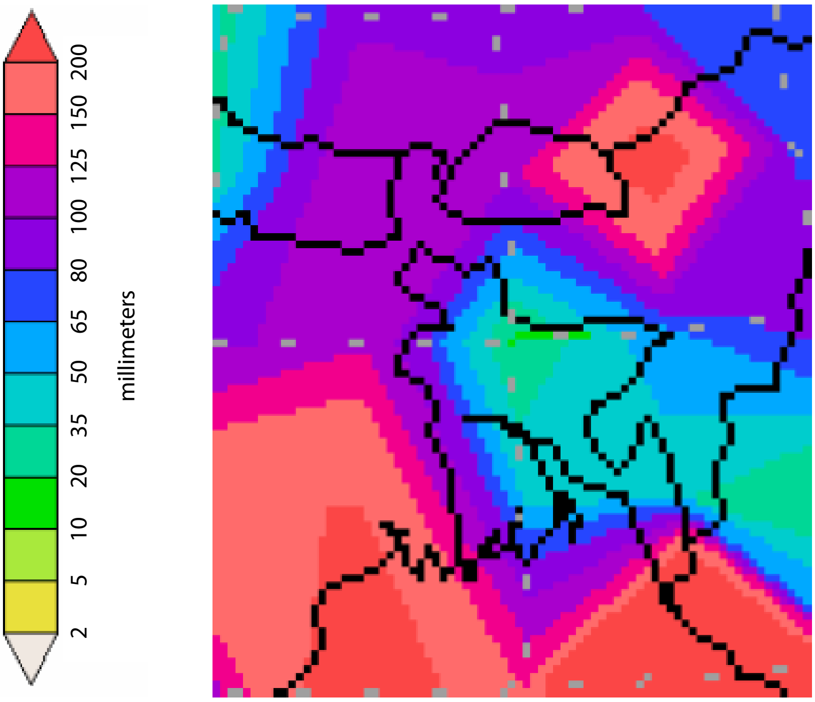


Figure 1.4. Three spatial maps of the weekly agro meteorological forecast from BMD: (a) spatial distribution of rainfall, (b) accumulative rainfall and (c) extended outlook for accumulative rain.

Flood forecasting
The total catchment area covered is 82,000 km2, under 216 catchments where the total length of modeled rivers is 7270 km. Total number of forecast stations is 30, as shown in Figure 1.5. FFWC provide forecasts on floods as water level above danger level in the river during pre-monsoon, monsoon and post-monsoon seasons. However, it doesn't provide forecasts on the internal flooding, tidal flooding and storm surge flooding. Table 1.1 shows the station and corresponding river name where FFWC has generated water level forecast information.

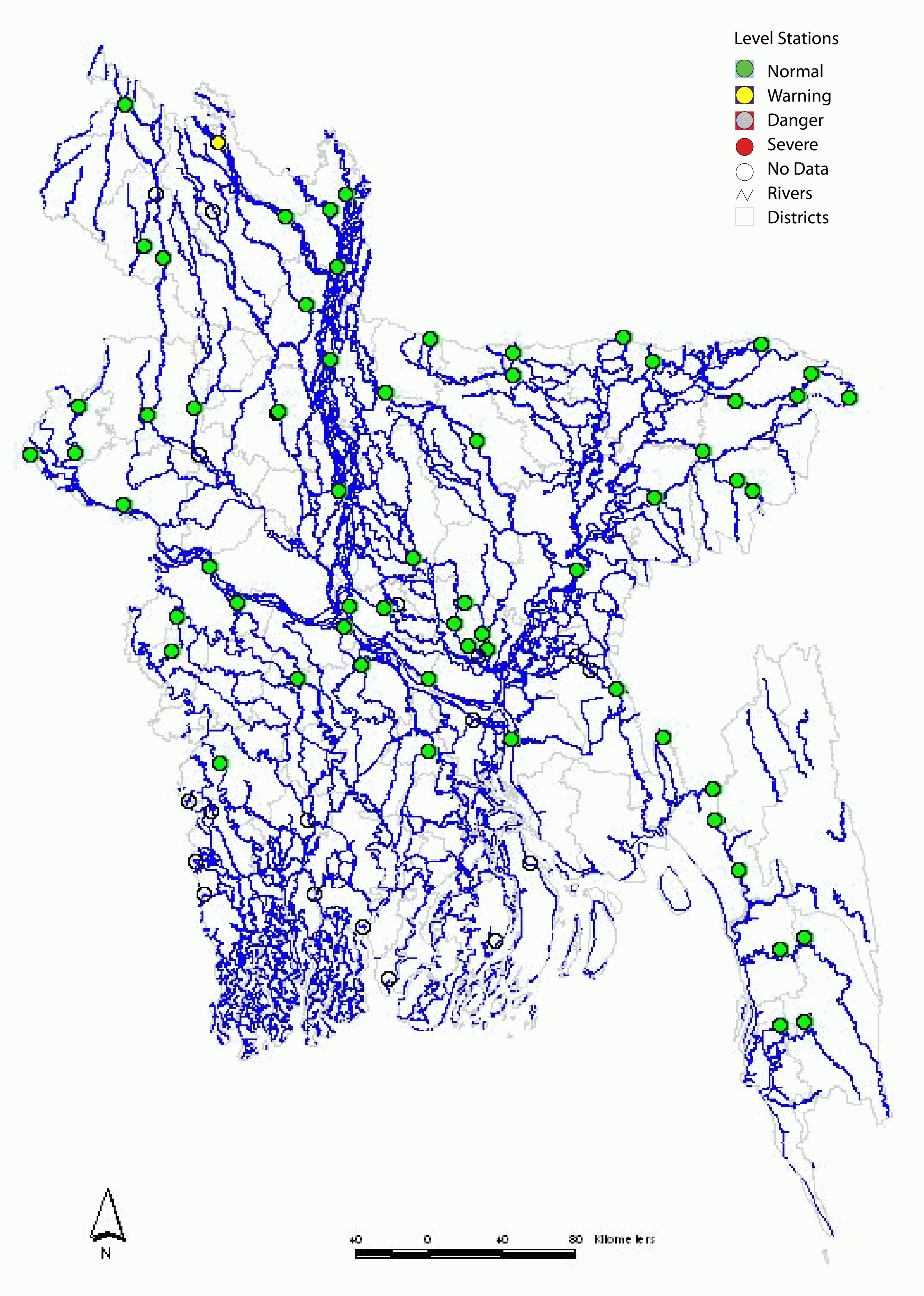


Figure 1.5. Maps of stations where flood forecast information is generated by the Flood Forecasting and Warning Center (FFWC).

Table 1.1. Basin-wise list of water level stations on the rivers where flood forecasting information is generated by the Flood Forecasting and Warning Center (FFWC).

Brahmaputra Basin		Ganges Basin		Meghna Basin		South Eastern Hill Basin	
River	Station	River	Station	River	Station	River	Station
Dharla	Kurigram	Karatoya	Panchagarh	Surma	Kanaighat	Muhuri	Parshuram
Teesta	Dalia	Punarbhaba	Dinajpur	Surma	Sylhet	Halda	Narayan Hat
Teesta	Kaunia	Ich-Jamuna	Phulbari	Surma	Sunamganj	Halda	Panchpukuria
Jamuneswari	Badarganj	Tangon	Thakurgaon	Kushiyara	Amalshid	Sangu	Bandarban
Ghagot	Gaibandha	Upper Atrai	Bhusirbandar	Kushiyara	Sheola	Sangu	Dohazari
Karatoya	Chakrahimpur	Mohananda	Rohanpur	Kushiyara	Sherpur	Matamuhuri	Lama
Karatoya	Bogra	Mohananda	Chapai Nawabganj	Sarigowain	Sarighat	Matamuhuri	Chiringa
Brahmaputra	Noonkhawa	Little Jamuna	Naogaon	Manu	Chatlaghat	Feni	Ramgarh
Brahmaputra	Chilmari	Atrai	Mohadevpur	Manu	Manu Rly Bridge	Karnafuli	Sadarghat
Jamuna	Bahadurabad	Padma	Pankha	Manu	Moulvi Bazar	Karnafuli	Kalurghat
Jamuna	Serajganj	Padma	Rajshahi	Khowai	Ballah	Ichaati	Thandachori
Jamuna	Aricha	Padma	Hardinge Bridge	Khowai	Habiganj	Naf	Teknaf
Old Brahmaputra	Jamalpur	Padma	Goalondo	Bhugai	Nakuagaon		
Old Brahmaputra	Mymensingh	Padma	Bhagyakul	Jadukata	Lourergorh		
Buriganga	Dhaka	Gorai	Gorai Rly Bridge	Someswari	Durgapur		
Balu	Demra	Gorai	Kamarkhali	Kangsha	Jariajanjail		
Lakhya	Narayanganj	Ichamati	Shakra	Meghna	Bhairab Bazar		
Turag	Mirpur	Betna	Kalaroa	Gumti	Comilla		
Tongi Khal	Tongi	Matha-bhanga	Chuadanga	Gumti	Debiddar		
Kaliganga	Taraghat	Matha-bhanga	Hatboalia	Meghna	Chandipur		
Dhaleswari	Jagir	Kobadak	Jhikargacha	L.Meghna	Daulatkhan		
Dhaleswari	Rekabibazar	Kumar	Faridpur	Gumti	Kangsanagar		
Bangshi	Nayarhat	Arialkhan	Madaripur	Gumti	Jibanpur		
Atrai	Atrai	Tentulia	Dasmunia	Dhaleswari	Kalagachia		
Atrai	Singra	Rupsa- Passur	Mongla	Meghna	Baider Bazar		
Jamuna	Mathurapara	Bishkhali	Patherghata	Meghna	Meghna Bridge		
Jamuna	Kazipur	Baleswar	Rayenda				
Jamuna	Porabari	Padma	Mawa				
Old Brahmaputra	Toke	Rupsa	Khulna				
Buriganga	Hariharpara	Padma	Talbaria				
Lakhya	Lakhpur	Padma	Sengram				
		Padma	Mohend-rapur				

1.5 Degree of certainty and specification

There is no official information available regarding the degree of certainty of the forecast product of BMD. However, the degree of certainty and lead time of forecasting of rainfall needs improvement. Similar observations have been found from the participants of field visits. Location-specific information about storm surge level is not available at this moment, and hence is of limited applicative use for authorities, communities and other stakeholders dependent upon timely and accurate forecasting.

Forecasting from FFWC is reasonably accurate for the very short duration of 3 days. However, the accuracy suffers when lead times increase.

1.6 Limitations, constraints and opportunities

There is an evident need for more timely, accurate and effective weather forecasting mechanisms and processes in Bangladesh. This has been recognized by Bangladesh authorities, international institutions and the research community for many years and as a result has seen a great deal of investment in these areas. However, there are a number of issues with regard to forecasting that still need to be addressed.

The present cyclone forecasting system lacks accuracy for storm surge forecasting. The system can be improved by predicting storm surge using high performance computation facilities. Using such improved facilities, it is possible to generate storm surge information well before cyclone. Figure 1.6 shows storm surge maps generate using Advanced Circulation (ADCIRC) model by a Bangladeshi scientist, Dr Hassan Mashriqui, working at the Louisiana State University (LSU). This map was generated by using LSU's super computer about 12 hours before it impacts on the coast. Dr. Mashriqui developed this storm surge map and sent it to Bangladeshi emergency management officials in time to warn and evacuate people from high risk areas. This is a clear illustration of how improved computational application can lead to improved outcomes for human welfare.

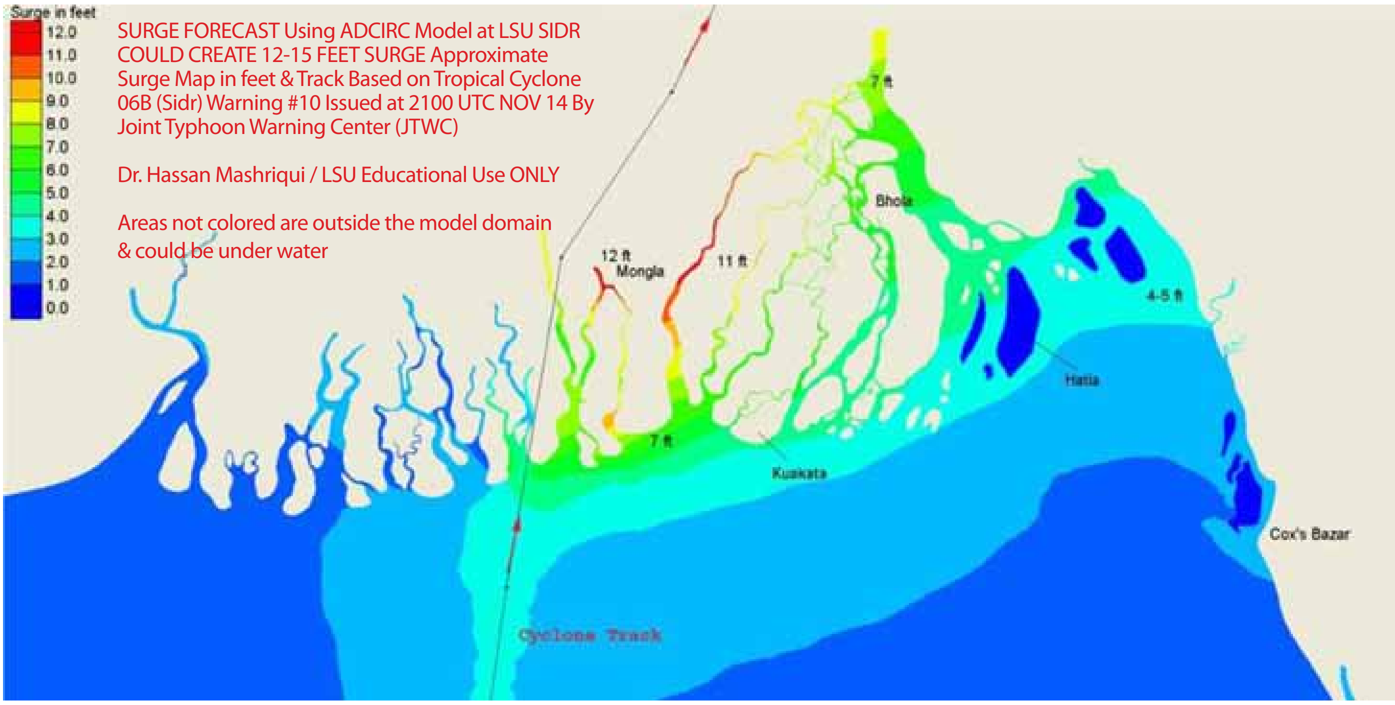


Figure 1.6. The storm surge map of Cyclone Sidr.

In order to achieve further improvements in analysis, information dissemination/communication, forecasting and, ultimately, on-ground outcomes, it is also essential to hire experts to work full- time at BMD. Additionally, Government should encourage and fund research on numerical weather predictions and storm surge predictions though various national centers, NGOs and universities.

Lead time of the flood forecasting is only 72 hours, which is not sufficient for planners and decision-makers. Long-term flood forecasting is necessary to mitigate loss and damages caused by floods.

Seasonal weather forecasting is also essential for agricultural sectors. Accurate seasonal weather forecast information should be available to the farmers to help them better prepare for natural disasters (such as drought and floods).

Chapter two: Dissemination of information

2.1 Priority stakeholders, and past and on-going projects

2.1.1 International

International organizations take an active role in the event of natural disasters occurring. The following organizations provide assistance through the provision of information, advice and cooperative and collaborative assistance to the national organizations.

- World Meteorological Organization (WMO) provides real-time data and information through the global telecommunications system to BMD, who also provide expertise and guidance materials to BMD and the Department of Hydrology.
- World Health Organization (WHO) provides help and advice to the Governmental and non- Governmental health sectors through its Country Office in Dhaka, Bangladesh.
- International Red Cross and Crescent Societies through the Bangladesh Red Crescent Society (BDRCS) administrates the Cyclone Preparedness Programme (CPP) in cooperation with the Disaster Management Bureau (DMB).

2.1.2 National

The following committees operate during climatic disasters (e.g. cyclone and storm surge) in relation to dissemination, monitoring and conducting relief activities:

- National Disaster Management Council (NDMC), headed by the Prime Minister to formulate and review disaster management policies and issues directives addressing Early Warning System key stakeholder and partner concerns.
- Inter-Ministerial Disaster Management Co-ordination Committee (IMDMCC), headed by the Minister in charge of the Ministry of Food and Disaster Management (MoFDM), to implement disaster management policies and decisions of the NDMC.
- National Disaster Management Advisory Committee (NDMAC), headed by a suitably qualified and experienced person, nominated by the Prime Minister.
- Cyclone Preparedness Program Implementation Board (CPPIB), headed by the Secretary, Ministry of Food and Disaster Management, to review the preparedness activities in the face of initial stages of an impending cyclone.
- Disaster Management Training and Public Awareness Building Task Force (DMTATF), headed by the Director General of Disaster Management Bureau (DMB) to

co-ordinate the disaster-related training and public awareness activities of the Government, NGOs and other organizations.

- Focal Point Operation Coordination Group of Disaster Management (FPOCG), headed by the Director General of DMB, to review and co-ordinate the activities of various departments/agencies related to disaster management and also to review the Contingency Plan prepared by concerned departments.
- NGO Coordination Committee on Disaster Management (NGOCC), headed by the Director General of DMB, to review and co-ordinate the activities of concerned NGOs in the country.
- Committee for Speedy Dissemination of Disaster Related Warning/Signals (CSDDWS), headed by the Director General of DMB, to examine, ensure and determine the most expedient ways and means for the rapid and timely dissemination of warnings/signals among the people.

2.1.3 NGOs

Non-government organization (NGO) activity in Bangladesh began in earnest in 1970, when the country struggled to cope with, then rebuild from, the devastating cyclone of that year Then followed the War of Independence in 1971 (Sobhan, 1997). In more recent times, floods and cyclones remain the primary natural disasters during and after which NGOs become involved (Matin and Taher, 2001). A number of NGOs were found to be active during Cyclone Sidr, evacuating people and disseminating cyclone warnings. The degree of activity by NGOs and, crucially, the acceptance by the government that they have a legitimate role to play, have increased in recent years, although there can be confusion about the respective roles and responsibilities of each entity during times of disaster (Matin and Taher, 2001). The lack of clarity regarding roles and strategic location of activities has been highlighted by Fruttero and Gauri (2005), who found that many NGOs in Bangladesh will not necessarily focus their activities where they are most sorely required, but rather where they do not currently have an organizational presence. This can lead to a doubling-up of efforts with other NGOs in a given location.

Recent cyclone responses by NGOs include but are not limited to:

- OXFAM providing emergency response to over 110,000 people in south-west Bangladesh, providing temporary shelters, safe sanitation and establishing water treatment plants to provide safe drinking water;
- CARE Bangladesh disaster preparedness study, as one of the strategic objectives under the Strengthening Household Ability to Respond to Development Opportunities (SHOUHARDO) Program, which included assessments of the country's district forecasting and early warning systems (http://www.carebangladesh.org/publication/Publication_6422837.pdf).
- BRAC aims to "move beyond relief and rehabilitation and into institutionalized preparedness, risk reduction and management interventions as well as long-term adaptation strategies" (http://www.brac.net/content/disaster-environment-climate-change) through its Disaster, Environment and Climate Change program. The program evolved as a result of the experiences during Cyclone Sidr, and has a number of objectives that relate to forecasting and information dissemination, e.g. to build capacity at the community level to face natural disasters due to climate change. The program consists of research, development and implementation activities that relate to establishment of microclimatic weather stations, standard operating procedures to improve organization rapid response when natural disasters occur, improved and systematic dissemination of weather warnings, and training programs to improve community awareness of and preparedness for natural disasters.
- Muslim Aid operates in Bangladesh, running disaster risk reduction and climate change adaptation programs. These programs relate to pertinent issues such as strengthening preparedness and response capacity in flood- and cyclone-prone areas in Bangladesh; it includes a comprehensive approach to education of the risks of disasters and climate change and how communities can be better prepared to deal with them.

It is evident that there is a considerable role for NGOs to work in conjunction with government departments and institutions. Accordingly, a range of NGOs already operates in the areas of disaster relief, community health, weather forecasting, information dissemination and broadcast and community education and empowerment.

2.1.4 Local

In the event of a tropical cyclone, the CPP receives the cyclone warning signals from Storm Warning Centre (SWC) of the Bangladesh Meteorological Department (BMD) as soon as a depression is formed in the Bay of Bengal. The information is transmitted to the six zonal offices over HF radio as shown in Figure 2.1. The Assistant Directors, in turn, pass it on to Unions through VHF radio. Where VHF radio has not yet been installed, the messenger then relays the message. The Union Team Leaders immediately contact the Unit Team Leaders (Figure 2.2). The Unit Team Leaders, in association with their volunteer network, spread out in the villages and disseminate the cyclone warnings, almost door-to-door, using megaphones, hand sirens and public address systems. Meanwhile, the Team Leaders keep track of the approaching cyclone by listening to national radio broadcasts over transistor radios. Team Leaders are thus alerted and able to start work without losing valuable time. The volunteers continue announcing the special weather bulletins regarding the characteristics of the approaching cyclone, as per their action plan.

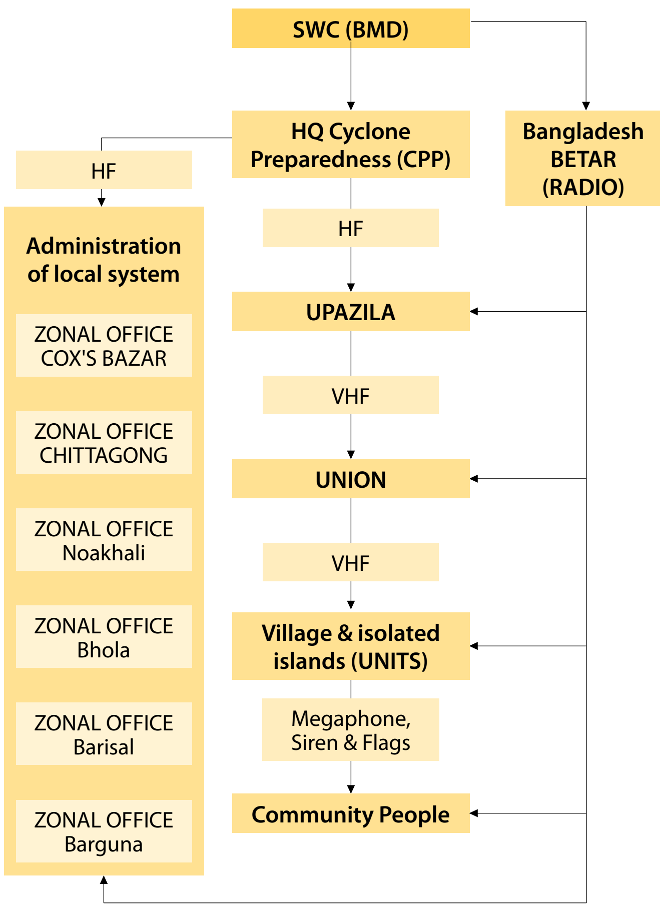


Figure 2.1. Dissemination of warnings and signals from the Storm Warning Centre (SWC) of Bangladesh Meteorological Department (BMD) through the Cyclone Preparedness Program (CPP) to the community people.

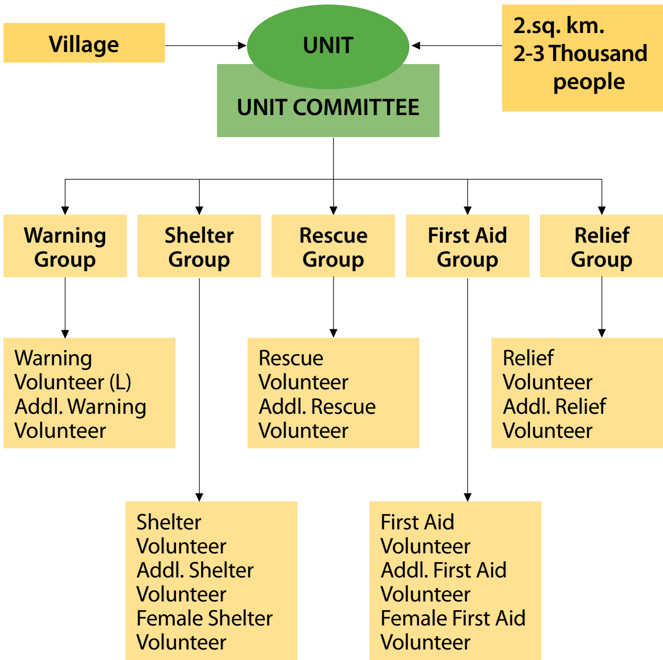


Figure 2.2. Cyclone Preparedness Programme (CPP) organization from Unit level showing communication stream of warnings, subsequent mobilization and groups involved [Source: *Arjumand et al.* (2012)].

2.1.5 Access to information for researchers

Researchers can obtain information relating to past floods and cyclones from the Bangladesh Water Development Board (BWDB) and BMD database. However, information pertaining to the storm surge levels at various coastal locations hit by the cyclone is not collected.

2.2 Dissemination strategy

There are two stages to the Bangladesh Meteorological Department issuing their weather warnings:

Stage 1—Alert Stage

a. Issue as soon as possible the alert warning signals of a cyclone, at least 36 hours ahead of formation of depression in the Bay of Bengal;
b. Supply information through fax/telephone/teleprinter to the Cyclone Preparedness Programme (CPP) about the formation of a depression in the Bay of Bengal, so that the CPP may take appropriate action, including dissemination of information to priority stakeholders;
c. Issue warning signals code *Whirlwind* to all concerned officials through telephone, teleprinter, telegram, fax, email, etc.;
d. Prepare and submit Special Weather Bulletin and broadcast/publicise the same through national news media, such as, radio and television stations and in national newspapers, for the benefit of the general public. In case of Local Cautionary Signal No. 3, arrange for adequate and full-time coordination between SWC of the Meteorological Department, Bangladesh Betarand Bangladesh Television for publicity outside normal broadcasting hours.
e) Send Special Weather Bulletins to the Emergency Operations Centre (EOC) at the Ministry of Disaster Management and Relief, the Directorate of Relief and Rehabilitation, the Cyclone Preparedness Programme and Bangladesh Red Crescent Society to ensure adequate arrangements are implemented.

Stage 2—Warning Stage

Publicize warning signals at each of the following specified stages using the all the available means, e.g. radio, TV, web, fax, telephone, teleprinter.

a. 'Warning' 24 hours before.
b. 'Danger' at least 18 hours before.
c. 'Great Danger' at least 10 hours before.

The same warning signals are then repeated to the Emergency Operations Centre (EOC) at the Ministry of Disaster Management and Relief, Control Room of the Disaster Management Bureau, the Directorate of Relief and Rehabilitation, the Cyclone Preparedness Programme and the Bangladesh Red Crescent Society. The following data are mentioned in the signals to be disseminated:

a. Position of the storm center
b. Velocity and direction of the storm
c. Mention of the Upazilas of the districts likely to be affected, when possible
d. Appropriate time of commencement of gale force wind at different places—velocity above 32 miles/hour (51.84 km/hour).

Flood warning dissemination

Information of riverine floods occurring during pre-monsoon, monsoon and post monsoon season are sent on a daily basis to the following national organizations: President's Office

- Prime Minister's Office.
- Ministry of Water Resources.
- Ministry of Relief and Rehabilitation.
- Disaster Management Bureau.
- Army Headquarters.
- Public Information Department.
- Government departments.
- News agencies—radio & TV.
- NGOs and International relief organizations (e.g. MSF, Red Cross/Crescent).
- Foreign embassies and consulates in Dhaka.
- Field wireless stations.
- Other recipients, as directed by the Disaster Management Bureau.

2.3 Tools of dissemination

Flood warning dissemination

The following systems have been used to disseminate flood warnings

- Internet—Flood warning has been updated daily during the monsoon season in the FFWC web site at http://www.ffwc.org.
- Email—Flood warning bulletin is sent daily to the relevant organizations and important stakeholders during the monsoon season.
- Fax, Telephone & Wireless—Flood information has been sent daily to District Disaster Management offices.
- Radio & Television—During severe floods, warnings have been published in the electronic and print media.

Cyclone warning dissemination

The following systems have been used to disseminate cyclone warnings:

- Internet—Information is available from the BMD website at http://www.bmd.gov.bd.
- Email—Emails sent to relevant organizations and stakeholders.
- Fax, Telephone & Wireless—Warnings provided through these media to the local DMB offices.
- Radio & Television—Hourly bulletins of cyclone warnings are published in the electronic media.
- Disaster Management Bureau and Committees—BMD provides warning to the DMB and local disaster management committees.

A number of committees, as mentioned previously, have been activated and coordinated to monitor the cyclone and storm surge. Figure 2.3 shows a schematic of the cyclone warning dissemination systems in Bangladesh.

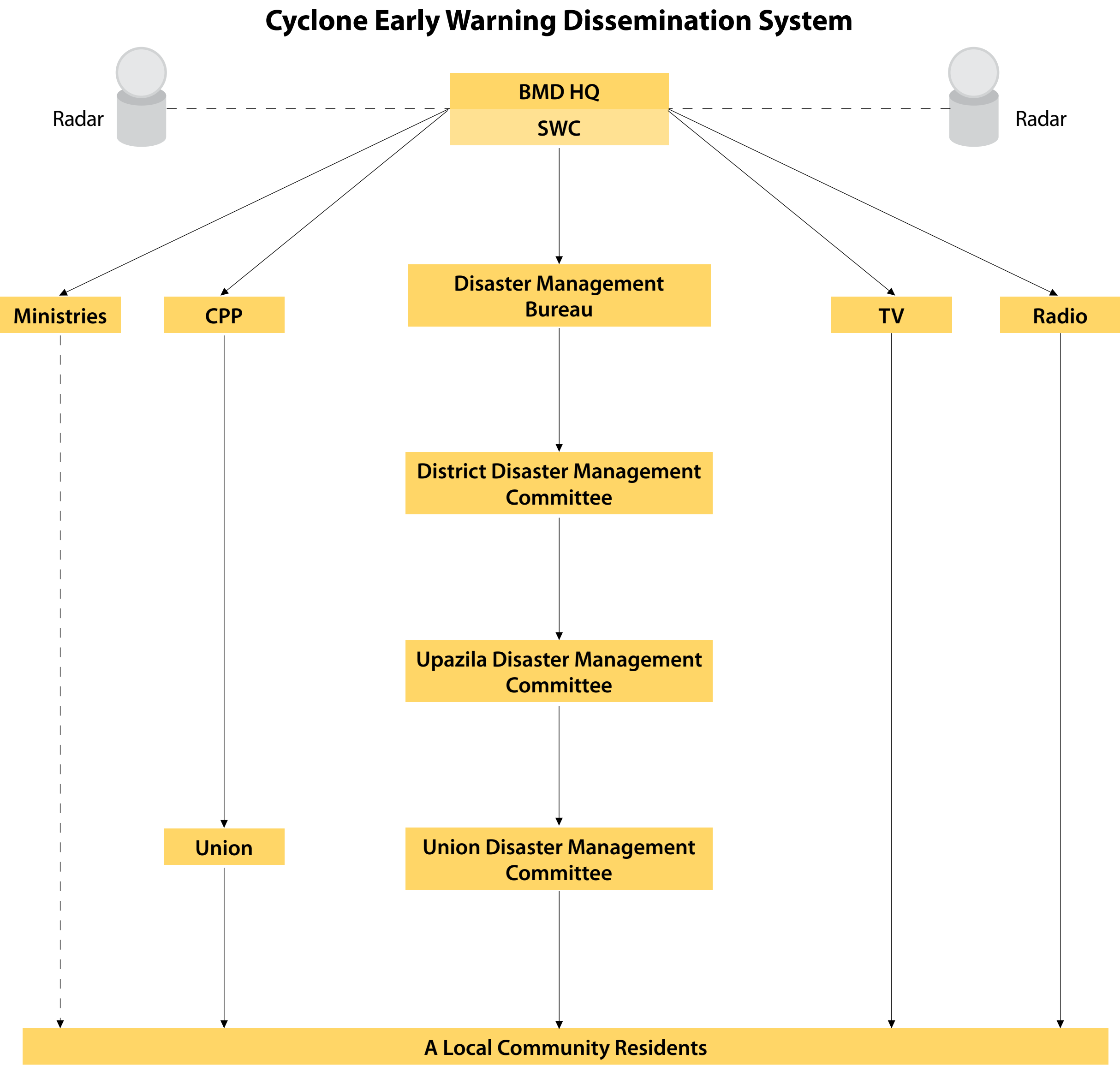


Figure 2.3. Cyclone warning dissemination systems [Source: *Arjumand et al.* (2012)]. Radar operation is for limited hours during the day which is shown as dotted arrow.

2.4 Geographical scale and coverage

Weather forecasting from BMD has been disseminated throughout Bangladesh via radio, TV, internet, etc. Figure 2.4 shows a typical experimental 24-hour rainfall forecast map generated by the Weather Research and Forecasting model.

Flood forecasting and warning information has also covered the whole country. For instance, 3- day forecasts have been provided for a total of 30 stations located on the major rivers in Bangladesh. Water levels above danger level for the following 72 hours have been provided for these stations. Flood inundation maps for the whole country have also been prepared. Figure 2.5 shows a typical flood inundation map based on forecasts of the next 48 hours.

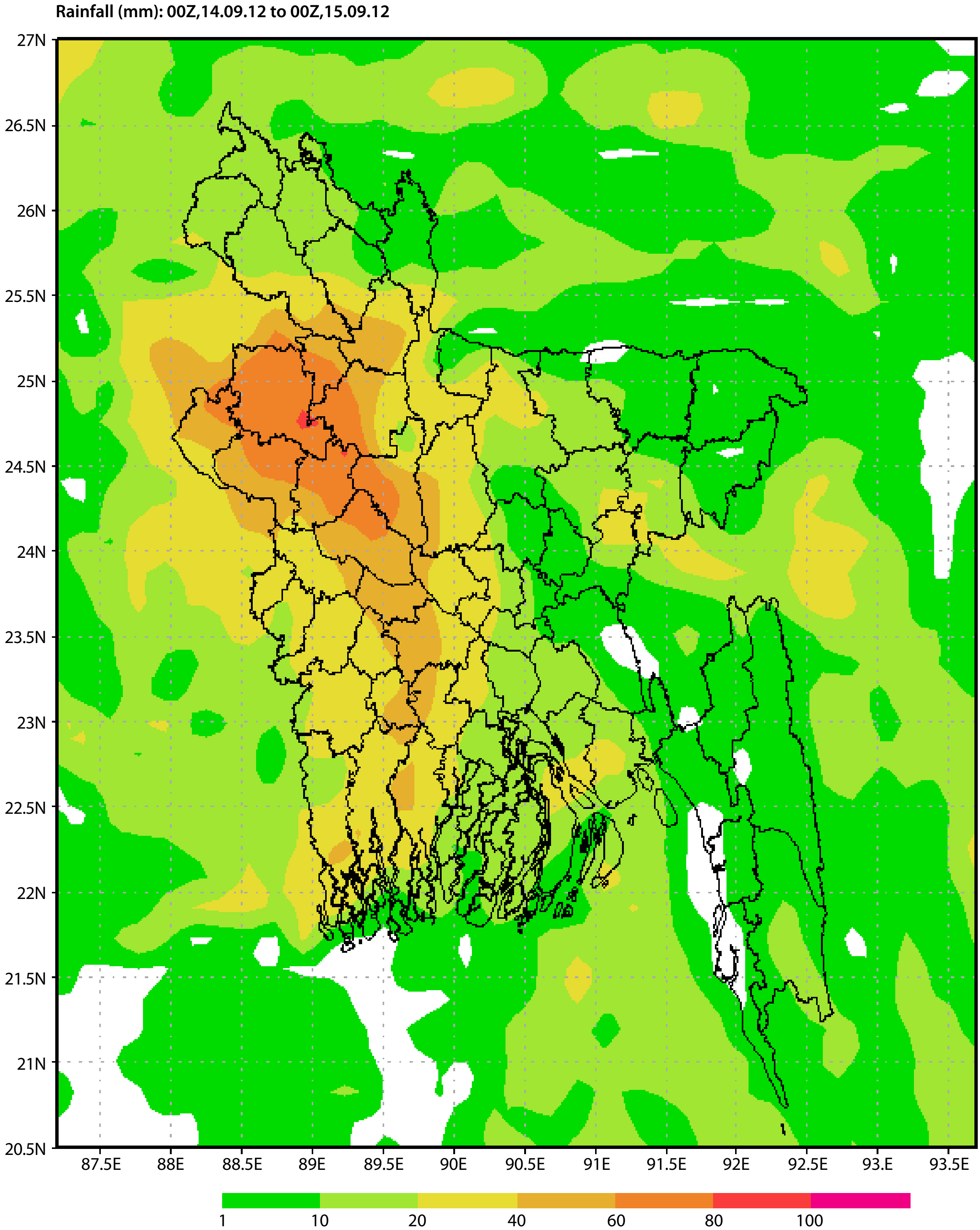


Figure 2.4. A typical experimental 24-hour rainfall forecast map generated by the WRF model. The y axis represents latitude, the x axis longitude. Rainfall measurements are in mm. District boundaries are depicted as black outlines.

Flood forecasting and warning information has also covered the whole country. For instance, 3- day forecasts have been provided for a total of 30 stations located on the major rivers in Bangladesh. Water levels above danger level for the following 72 hours have been provided for these stations. Flood inundation maps for the whole country have also been prepared. Figure 2.5 shows a typical flood inundation map based on forecasts of the next 48 hours.

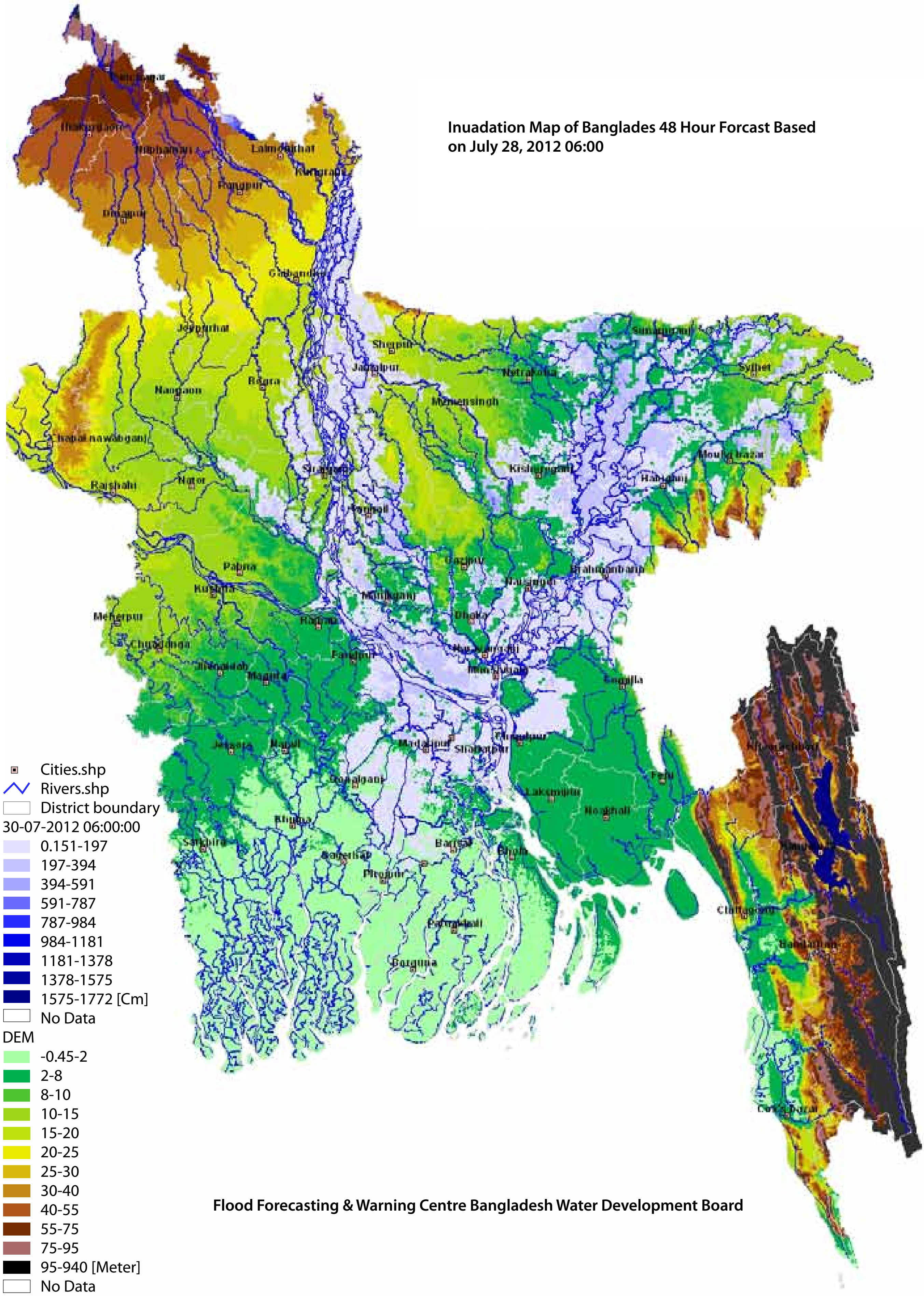


Figure 2.5. A typical 48-hour flood inundation map of Bangladesh, using data from the Flood Forecasting & Warning Centre of the Bangladesh Water Development Board.

2.5 Degree of certainty and specificity

The weather forecasting information has been disseminated and coordinated by the afore-mentioned systems. Performance of these dissemination systems is improving though they have suffered from inaccuracy. The total death toll per cyclone has been gradually reduced for four major cyclones that have hit coastal areas of Bangladesh since 1991. Rainfall forecasting has frequently been observed to be somewhat inaccurate, or often depicts meteorological events at coarse scales, and as such often does not fulfill the information requirements of local communities. Heavy rainfall events, unseasonal rainfall and drought predictions need to be included in the present dissemination system, in order to improve predictive capability and to be of greater practical use to communities.

Flood forecasting has also occurred using the above communication media. However, it suffers from the incapacity to predict the rise of flood level with respect to each local community. Community-based flood forecasting and warning systems should be introduced to disseminate location-specific flood information to the villagers. Lead time of forecasting should be increased for better flood management.

2.6 Signal system and typical weather forecasts of the BMD

During the cyclone and storm surge the BMD issues two types of warning signals—those for maritime ports and those for inland river ports. Table 2.1 presents signals used for maritime ports with their respective thresholds and Table 2.2 represents the signals used for inland river ports with their respective thresholds. There has been no signal issued considering the conditions of devastation and damage over land. Community-based warning for the cyclone and storm surge was not disseminated.

Table 2.1. Signal system for maritime ports with thresholds.

Signal No.	Signals	Explanation/threshold
1	Distant Cautionary Signal Number I	There is a region of squally weather in which a storm may be forming (well-marked low or depression) with surface winds up to 61 km/h. (33 knots)
2	Distant Warning Signal Number II	A storm has formed—cyclonic storm with surface winds 62– 87 km/h. (34–47 knots)
3	Local Cautionary Signal Number III	The port is threatened by squally weather—cyclonic circulation with surface winds 40–50 km/h. (22–27 knots). Also squalls and due nor'westers
4	Local Warning Signal Number IV	The port is threatened by a storm, but it does not appear that the danger is as yet sufficiently great to justify extreme measures of precaution (cyclonic circulation) with surface winds 51–61 km/h (28–33 knots)
5	Danger Signal VI	The port will experience severe weather from a cyclonic storm of moderate intensity—cyclonic storm with surface winds 62–88 km/h (34–47 knots)
6	Great Danger Signal VIII	The port will experience severe weather from a storm of great intensity—severe cyclonic storm with surface winds 89–117 km/h (48–63 knots)
7	Great Danger Signal IX	The port will experience severe weather from a storm of very great intensity—severe cyclonic storm with a core of hurricane winds with surface winds 118–170 km/h (64–119 knots)
8	Great Danger Signal X	The port will experience severe weather from a storm of very great intensity—severe cyclonic storm with a core of hurricane winds with surface winds 171 km/h and above (120 knots and above)

Table 2.2. Signal system for inland river ports with thresholds

Signal No.	Signals	Explanation/threshold
1	Local Cautionary Signal Number III	The area is threatened by squally winds of transient nature (nor'wester squall of wind speed 40–50 km/h (22–27 knots)). Look out for further development.
2	Local Warning Signal Number IV	A storm (of depression intensity, associated sustained winds 51–61 kph (28–33 knots) or nor'wester squalls (of wind speed 51–61 kph (28–33 knots)) is likely to strike the area. Vessels of length 65 feet or less are to seek shelter immediately.
3	Danger Signal VI	A storm of moderate intensity or nor'wester squalls, associated sustained winds 62–88 km/h (34–47 knots) may strike the area. All vessels are to seek shelter immediately and keep in shelter until further notice.
4	Great Danger Signal VIII	A violent storm or nor'wester, associated sustained wind 89–117 km/h (48–63 knots) may strike. All marine vessels have to keep in shelter until further notice.
5	Great Danger Signal IX	A very severe cyclonic storm with very high intensity with sustained wind 118–170 km/h (64–119 knots) may strike. All marine vessels are to be in shelter until further notice.
6	Great Danger Signal X	A very severe cyclonic storm with the intensity of super cyclone with sustained wind of 171 km/h or more (120 knots or more) may strike. All marine vessels are to be in shelter until further notice.

Table 2.3 provides an example of typical weather forecasts from BMD for next 12 hours for major regional divisions of Bangladesh.

Table 2.3. A typical example of weather forecast from the Bangladesh Meteorological Department, which is valid for 12 hours.

Regional divisions	Forecast
Dhaka	**Sky**: Partly cloudy to cloudy. **Weather**: Light to moderate rain/temporary showers accompanied by temporary gusty wind is likely to occur at many places over the area with moderately heavy falls at places. **Temperature**: Day and night temperatures may remain nearly unchanged over the area. Yesterday's maximum temperature of Dhaka city 29.2°C. Today's minimum temperature of Dhaka city 26.6 °C.
Chittagong	**Sky**: Partly cloudy to cloudy. **Weather**: Light to moderate rain/temporary showers accompanied by temporary gusty wind is likely to occur at many places over the area with moderately heavy falls at places. **Temperature**: Day and night temperatures may remain nearly unchanged over the area. Yesterday's maximum temperature of Chittagong city 30.0°C. Today's minimum temperature of Chittagong city 26.0°C.
Rajshahi	**Sky**: Partly cloudy to cloudy. **Weather**: Light to moderate rain/temporary showers accompanied by temporary gusty wind is likely to occur at many places over the area with moderately heavy falls at places. **Temperature**: Day and night temperatures may remain nearly unchanged over the area. Yesterday's maximum temperature of Rajshahi city 30.8°C. Today's minimum temperature of Rajshahi city 25.5°C.
Rangpur	**Sky**: Partly cloudy to cloudy. **Weather**: Light to moderate rain/temporary showers accompanied by temporary gusty wind is likely to occur at many places over the area with moderately heavy falls at places. **Temperature**: Day and night temperatures may remain nearly unchanged over the area. Yesterday's maximum temperature of Rangpur city 26.5°C. Today's minimum temperature of Rangpur city 24.6°C.
Khulna	**Sky**: Partly cloudy to cloudy. **Weather**: Light to moderate rain/temporary showers accompanied by temporary gusty wind is likely to occur at many places over the area with moderately heavy falls at places. **Temperature**: Day and night temperatures may remain nearly unchanged over the area. Yesterday's maximum temperature of Khulna city 32.0°C. Today's minimum temperature of Khulna city 26.5°C.
Barisal	**Sky**: Partly cloudy to cloudy. **Weather**: Light to moderate rain/temporary showers accompanied by temporary gusty wind is likely to occur at many places over the area with moderately heavy falls at places. **Temperature**: Day and night temperatures may remain nearly unchanged over the area. Yesterday's maximum temperature of Barisal city 28.0°C. Today's minimum temperature of Barisal city 25.4°C.
Sylhet	**Sky**: Partly cloudy to cloudy. **Weather**: Light to moderate rain/temporary showers accompanied by temporary gusty wind is likely to occur at many places over the area with moderately heavy falls at places. **Temperature**: Day and night temperatures may remain nearly unchanged over the area. Yesterday's maximum temperature of Sylhet city 31.6°C. Today's minimum temperature of Sylhet city 25.0°C.

2.7 Limitations/constraints and opportunities

The present warning systems, despite the success of saving more lives during recent cyclones than in the past, have many limitations. Identified major limitations of disseminating weather forecasts are listed below:

- The present cyclone warning system is based on considering the river and marine conditions, ports and navigations. However, this system suffers from a paucity of useful information about the likely impacts on land that is in the vicinity of marine and river systems.
- The current warning system is not found accurate in terms of providing storm surge height information. Furthermore, it omits location-specific surge information, further reducing the practical applicability of the system.
- Flood forecasting presently provides short durational warning for the major rivers of the country. However, translating the information from the technical experts and authorities to the local community is largely absent. It is also important to increase the lead time of flood forecasting for agriculture and other sectors, in order that authorities and community members can respond accordingly and in a timely manner.
- The consequences of government forecasters inadvertently underestimating a storm's severity can be potentially catastrophic. For instance, the storms that hit southern Bangladesh's coastal districts on 12 October 2012 were not subject to a severe storm warning, with storm levels forecast at Warning Level III. When the storms hit they were described as Warning Level VII to VIII, and resulted in 500 fisherman from Bhola alone being missing at sea (Australian Broadcasting Corporation, 2012).
- The increase and decrease of water levels of floods with respect to the local datum are not provided.
- Seasonal forecast is essential for farmers. The BMD currently provides weekly agro- meteorological forecast for various regions of Bangladesh. However, location-specific agro- meteorological weather forecasts are needed for farmers, in order to increase the preparedness of the agricultural community.
- Information about risks and hazards for the community are not available within the present warning system. It often doesn't provide information about the preparedness of a community for the suite of potential weather hazards.

Although a number of NGOs and volunteers continue to work during a cyclone, it is essential to provide similar services for other weather-related disasters, e.g. floods and droughts.

- Under present agreements the with Indian Government, the Flood Forecasting and Warning Centre (FFWC) receives daily water level data from just a few gauge stations on the Ganges and Brahmaputra rivers. This is due to a lack of an adequate water treaty between India and Bangladesh, and requires that the Bangladesh authorities rely to a large extent on the upstream flow data from the Ganges, Brahmaputra, and Meghna rivers (Hossain and Katiyar, 2006). However, this information is not sufficient for an effective basin-wide flood forecasting information system for Bangladesh, as it provides a flood warning of only 2–3 days (Paudyal, 2002). More detailed information provision from areas further upstream in the major river systems (i.e. in India) would improve the predictive capacity (and on-ground utility) of the information system (Hossain and Katiyar, 2006). Flood events in Bangladesh are highly correlated with upstream events, with Chowdhury and Ward (2004) calculating that the timely provision of detailed and accurate upstream data could provide a flood warning of up to one month. More recent developments appear to indicate that the provision of data from India to Bangladesh may be increasing (Bagla, 2011 in Khan, 2012), but the forecasting situation could be greatly improved with an increase of data flow from Nepal, Bhutan, China and India (Khan, 2012).
- Despite the considerable efforts of government departments, international institutions, researchers and local stakeholders, there still appears to be limitations to local uptake and use of the weather forecast data made available. This appears to be particularly the case with regard to agricultural activities and management. There are a number of potential reasons for this. Weather event data may not be sufficiently localized to be of use (or perceived use) to land managers. For instance, Paul and Routray (2013) have identified that insufficient localization of data is a factor in locals not responding as anticipated to cyclone warnings. The same authors further identify another factor, relating to the accuracy of timing of landfall. It may be that the accuracy of predictions (or the perception of accuracy by the agricultural community) may be inhibiting response to warnings. Paul and Routray also offer a range of potential causes of lack of community responsiveness to warnings. These include: i) a high degree of fatalism among the community (Howell (2003) linked this to religious beliefs); ii) insufficient understanding of cyclone warnings (also reported by Howell, 2003); iii) previous experiences of inaccurate warnings; iv) pressure from employers and markets to keep producing goods; iv) traditional reliance on indigenous methods of weather forecasting (e.g. animal behavior).
- Other reasons maybe relate to the timing of events and warnings in relation to critical activities in the agricultural calendar. Often, it is not possible to abandon a crop, harvest early or move livestock en masse. This could be mistaken for recalcitrance or an unheeding approach, but in fact may represent a 'line of best fit' between the risk of altering management in response to a warning and the risk of not acting upon the warning. This may be more likely for more permanent crops (e.g. perennials), those with long growing times, or those that require significant infrastructure to produce; the social and financial cost of adapting (in the short term at least) may simply be too great, regardless of the severity of the warning.
- This need to integrate hazard/impact modeling with community adaptive capacity has been highlighted in Australian agricultural communities in relation to climate variability and climate change (Nelson et al. 2010), and is therefore not unique to Bangladesh. However, the very high levels of climate variability (historically, currently and future projected), combined with community poverty and a possible lack of understanding of the issues surrounding weather warnings, may lead to such situations being particularly prevalent in Bangladesh. These obstacles to adoption are not trivial, and a range of measures is likely needed to overcome them—examples are more localized weather data (Khan, 2012), increasing the resistance and resilience of farms (both physically and economically) to deal with increasing climate variability via crop and livestock diversification (Seo, 2009), and more effective and localized information dissemination practices.

Chapter three: Lessons learned from vulnerable coastal communities

3.1 Introduction

Field visits were made to the selected communities in the four CCAFS (Climate Change, Agriculture and Food Security) villages. In this visit, the primary objectives of the field visits were to:

- Assess the various types of natural and climatic hazards experienced by the communities;
- Identify the mechanism of weather forecasting and information dissemination techniques;
- Determine needs of weather information including degree of accuracy, lead time etc.;
- Assess the effectiveness of dissemination techniques and their coverage for the village communities.

Field visits were conducted during 15–18 June 2012 in the following four villages, whose locations are shown in Fig. 3.1:

A. Jagannathpur, in Jhalokhati district, Rajapur upazila under Suktagarhi union.
B. Gabgachia, in Bagerhat district, Morrelganj upazila under Daibgha union.
C. Harikhali, in Khulna district, Paikacha upazila under Soladana union.
D. Dumuria, in Satkhira district, Shymnagar upazila under Gabura union.

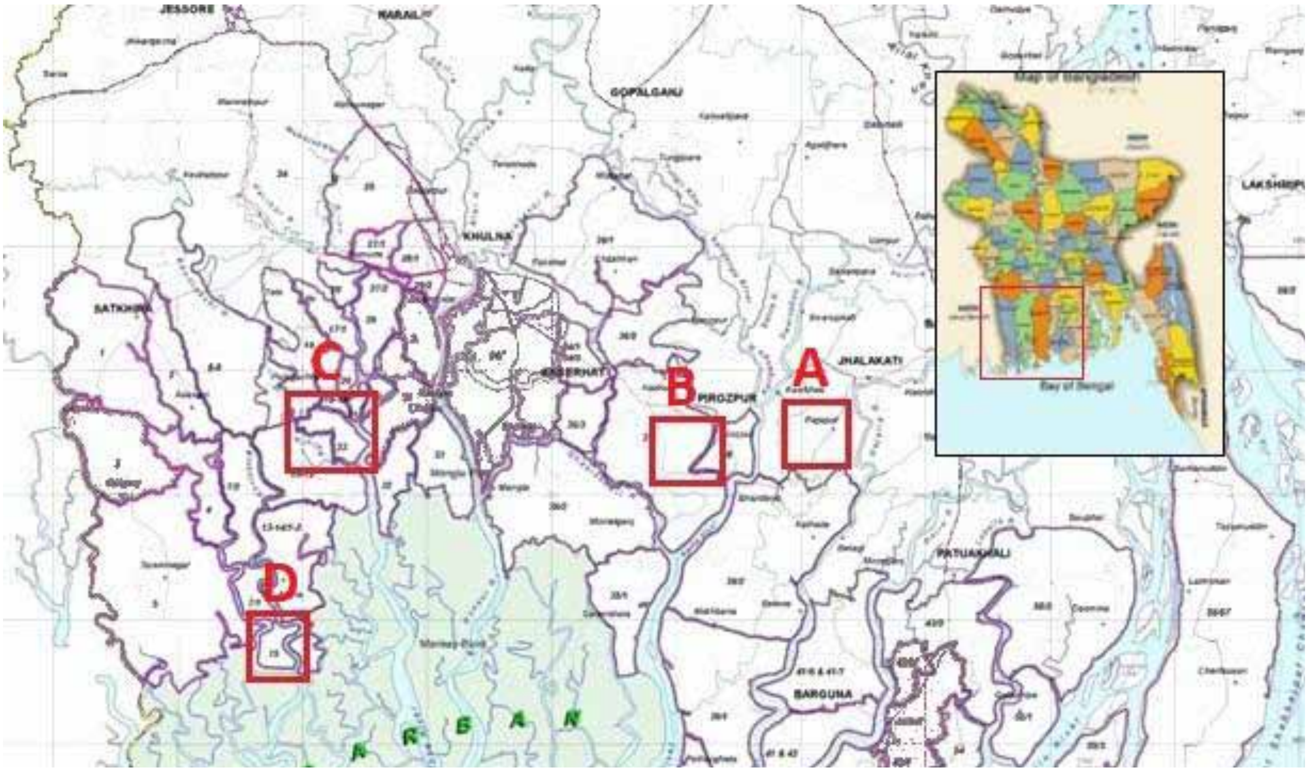


Figure 3.1. Locations of the four villages in the study.

Before conducting field visits, a discussion meeting was conducted with Mr. Kabir of WorldFish in order to determine the field situations based on his past experience of working in this area. It was found that these four villages have unique characteristics due to their geographic locations, river systems, and types of natural hazards and impacts they have experienced. Jagannathpur village is located in a fresh water area where a storm surge is not likely to be a major issue. On the other hand, Gabgachia village has both saline and fresh water issues. This village often experiences unseasonal rainfall and associated rainfall floods. Dumuria village is located very close to the sea and has suffered heavily from the recent cyclone Aila. This village also has salinity issues (although this heightened salinity can potentially help for shrimp farming). Harikhali has mixed conditions in terms of salinity. It has also recently been impacted and affected by the cyclone Aila.

During the field visit, group discussion was conducted among villagers with the help of local NGO staff who are partners of the WorldFish project. Both male and female community representatives were present in the group discussions and expressed their views, needs, and conditions of the vulnerability due to extreme events. A summary of the major findings for each individual village is presented in the following section.

3.2 Key findings from the field visits

Village: Dumuria

- This village was seriously affected by the recent cyclone Aila. Both strong winds and storm surges hit this village, as it is located very close to the sea.
- Due to shrimp cultivation, illegal breaches were made in the polder, and storm water entered through these breaches.
- Paddy fields, shrimp fields and houses were seriously damaged due to strong cyclonic wind and storm surges.
- A number of human casualties occurred due to the cyclone Aila. Many people climbed into trees for safety, or took shelter on the polders. The nearest cyclone shelter is far away (3 km) from the village and doesn't have adequate capacity to cope with a significant influx of people at any one time.
- Villagers received the cyclone warning information only 2 days before the cyclone impacted. However, the change of cyclone warning signal (corresponding to the intensity of the cyclone) was very rapid. For example, in the morning it was only classified as a signal 3 rating, whereas during the noon it was reclassified as a signal 7 rating. Water entered community houses at noon, immediately after the declaration of a signal 7 rating.
- Information regarding the cyclone was broadcast from national radio and television. However, those community members fishing at sea or occupied in the jungle (the Sundarbans) were unable to receive the cyclone forecast. Consequently, they were not able to respond to the threat announcement accordingly.
- There was no information available about the surge level and duration and timing of the storm surge.
- Apart from cyclones, farmers often suffer from heavy rainfall during the monsoon season, which damages their crops. There is no seasonal weather forecast system currently available and they only receive information from Ponjika (an astronomical diary) to predict monsoon rainfall, which is often not sufficiently accurate.
- The following suggestions were made by the villagers to improve cyclone forecasting and dissemination systems as well as disaster management:
    1. Many places in the polder have illegal breaches due to shrimp farming. It is essential to repair those breaches and maintain the polder regularly.
    2. Fresh water flow in the rivers and canals has reduced over the last few decades, due to interventions and withdrawal of water in the upstream part of the catchment. Heavy sedimentation occurring in the rivers and canal systems has increased sedimentation in the canal bed. It is essential to dredge the major rivers and canals to make adequate passage of storm waters in these systems and waterways.
    3. It is important to disseminate cyclone information well ahead of the event, with adequate accuracy to enable instigation of evasive or responsive action. Although the local people have received warnings, they lack the detailed information about the exact timing and

location of storm arrival and details of the possible extent and location of damage.

4. It is also essential to provide information about the storm surges and water depth/height using accurate weather forecasting systems.
5. New communication media, such as mobile phones, can be used for dissemination of cyclone information. [Note: Recently, the Disaster Management Bureau (DMB) has designed an integrated digital early warning approach in a combination of Cell Broadcasting Services (CBS), Short Message Services (SMS) and Interactive Voice Response (IVR) via mobile phones. Initially the warning systems will be disseminated through two mobile service operators—Grameenphone and Teletalk.]
6. It is important to construct a number of cyclone shelters or high-rise buildings (three to four storeys) such as schools, local government offices, or public sector offices, etc. in the villages.
7. It is essential to know the seasonal rainfall forecast for agriculture and fisheries activities at a spatial scale of sufficiently fine resolution to enable responses at local scales that are relevant to communities.

Photo 1. (a) Discussion with villagers from Dumuria (left) and (b) use of solar energy (right).

Photo 2. (a) Canals for shrimp farming (left) and (b) village roads (right).

Village: Jagannathpur

- This village has experienced floods during monsoon season which damage crops. Apart from paddy fields, fresh water fish and golda shrimp (a fresh water shrimp) are also affected due to heavy rainfall and flooding.
- A major problem of this village is siltation of major canals, which increases the flood height and prolongs floods. Heavy rainfall often causes flooding in this village due to the poor drainage system.
- Information on the intensity and duration of heavy rainfall was not available or disseminated to the villagers.
- Villagers also complained about the erratic nature of rainfall. In 2012, a severely below average amount of rainfall occurred during the pre-monsoon season and hence, the monsoon was delayed. This, in turn, has delayed the paddy crop plantings. There is no existing seasonal rainfall forecasting system for this area.
- Cyclone Aila has damaged crops and trees, houses, roads and fisheries. Major damage was caused by the strong winds associated with the cyclone. However, storm surge height and duration were not found to significantly influence damage rates or severity.
- Warnings about Cyclone Aila were received from national radio. While the warning provided information of the strength of the storm it did not provide location-specific information on surge height.
- Villagers have provided some suggestions to improve disaster forecasting and management which are listed below:
  1. Accurate information about the cyclone timing, location, trajectory, duration and strength, and the

associated storm surge is essential. It is also necessary to know this information with sufficient lead time to take evasive or responsive action.
2. Monsoon flooding can cause damage to crops and fisheries. Therefore, seasonal flood forecasting is essential. Villagers currently do not receive any kind of seasonal forecasting information, and consequently are unable to prepare accordingly.
3. Heavy rainfall forecasting will be helpful for saving crops.
4. Seasonal rainfall forecasting and crop insurance can minimize the crop losses experienced by farmers due to erratic or reduced rainfall, or other impacts such as flood events.
5. Major canals and river systems are silted and therefore need to be excavated/dredged.
6. New cyclone shelters or high-rise buildings (of suitably robust design and construction) need to be built in the village.

Photo 3. (a) Discussion with people from Jagannathpur (left) and (b) drainage canal and culvert (right).

Village: Gabgachia

- This village has experienced strong winds during cyclone Aila. Crops and fisheries were damaged from the strong winds and storm surge. Water was retained in the village for 4 days following the storm. This prolonged inundation exacerbates the extent and severity of water-induced damage, disrupts daily activity and communications, and can lead to increased incidence of water contamination and disease.
- In response, people stayed in the nearest high-rise building known as Mohila Proshikhan Center. However, the distance of the nearest cyclone shelter is 2.5 km from the village and capacity of the shelter is not adequate to accommodate all those requiring shelter.
- Storm surges come from the only open parts of the embankment at the Harmer Canal of the Daratana River. Ideally, a gate would be built that could restrict and control the passage of a storm surge. However, local shrimp farmers use the ingress of saline water, and would not agree to the construction of a sluice gate. Thus constructing a sluice gate in this location could create a conflict of interest among the villagers.
- Cyclone information was primarily disseminated to the villagers via the national radio services. The information about the storm surge was neither timely nor accurate.
- During the last year, excess rainfall in the monsoon season damaged crops. However, there is no seasonal rainfall forecasting available to the farmers, and hence they are unable to adjust their activities (e.g. initiate early harvest, postpone seed broadcast, relocate livestock) in response to impending weather events.
- There is no insurance for the farmers or fishermen to cope with natural disasters.
- The following suggestions were made by the villagers to improve the disaster forecasting and management options and responses:
  1. Accurate information about the storm surge is essential, as it can provide sufficient lead time for authorities and communities to prepare and respond.
  2. There is a need to construct a sluice gate in the Harmer canal to provide protection from storm surges and saline water intrusion into the village. However, some shrimp farmers prefer to have tidal flow through this gate all year round, while others want to preserve fresh water during the dry season. This dichotomy requires a resolution that is sustainable and addresses the concerns of all stakeholders.
  3. Seasonal forecasting of rainfall is important to the farmers in order to reduce losses from crop damage. It is also important to introduce and encourage crop insurance, in order to bolster communities financially when unavoidable losses do occur.
  4. There needs to be a number of cyclone shelters or high-rise buildings constructed in the community, in order to save lives of humans and reduce cattle losses during storms.
  5. The dissemination of cyclone information can be augmented via communication through alternative media, such as sending representatives or volunteers from Government or NGO, mobile phone SMS alerts, etc. However, the quality and accuracy of the warnings are essential in order to reduce damages.

Village: Harikhali

- This village was severely affected by the recent cyclone Aila. About eight people were killed in this village by the subsequent storm surge. Many livestock also died, and houses and trees were damaged by the strong winds.
- Fisheries were destroyed by the intrusion of storm surge water, which came through the breach in the polders. For shrimp cultivation, many illegal breaches were made in the polder which allowed the storm surge to more rapidly enter the village. Although these breaches were repaired within 10–15 days, the impacts were still sufficient to significantly impact the community and their livelihoods.
- Cyclone warnings were disseminated through radio, television and hand-held loudhailer microphones. Whilst dissemination can be effective, there are occasions where local communities have not believed the warnings (e.g. Sidr in 2007), or occasions where information arrived too

late for effective action to be taken.

- People took shelter in the nearest cyclone shelters and high-rise buildings and on the Local Government Engineering Department road.
- During the monsoon season, heavy rainfall also caused problems for fisheries and crops. Currently, there is no early warning for heavy rainfall in terms of duration and intensity available to the villagers. Hence the community is unable to adopt any evasive or adaptive actions.
- A lack of rainfall also causes an increase in soil salinity (dryland salinity), which can reduce crop and shrimp production, and can lead to an increase in water course pollution.
- The following suggestions were made by the villagers during the group discussion to improve cyclone warning and information dissemination:
  1. Although cyclone warnings have been provided, area-specific detailed information about a cyclone (trajectory, wind speed, timing, duration and storm surge height) is essential for saving human lives, protecting infrastructure and safeguarding livestock. Sufficient lead time is essential if communities are going to be better prepared and better able to respond to (increasing resistance to impacts), and recover from (increasing resilience to impacts), natural disasters.
  2. Seasonal rainfall forecasting can be helpful for farmers and fishers in terms of preparedness and adjusting management strategies to prevailing conditions.
  3. In particular, a heavy rainfall and flood forecasting system is required during the monsoon season.
  4. The dissemination of cyclone warnings should be improved by using new technologies such as mobile phone SMS. Changing the warning system to consider and incorporate storm surges is essential.

Photo 4. (a) Discussion with people from Harikhali (left) and (b) discussion with key informants (right).

Chapter four: Conclusions

This study focused on the present weather forecasting and dissemination systems of Bangladesh, and reached the following conclusions:

4.1 Weather and extreme event forecasting

- There is already a long history of investment and innovation in flood forecasting, both internationally and in Bangladesh in particular. In recent years, there have been clear, systematic and financially significant investments in weather forecasting in the region, as well as considerable research focus on improving cyclone and flood forecasting technology and capabilities in Bangladesh. Indeed, the known vulnerability of the region to extreme weather events, coupled with the presence of a vast and highly vulnerable human population, has meant that Bangladesh probably has one of the most technologically advanced and effective weather forecasting systems in the world. The MIKE11 system that underpins much of the forecasting continues to be incrementally upgraded and improved by its creators.
- The very nature of storm systems renders them unpredictable and likely to manifest rapidly and change trajectory/ severity unexpectedly. As such, predictions of storm movements, timing and severity can be subject to sudden change. This presents issues in relation to: i) providing timely and accurate information on extreme event occurrence to communities in the vicinity of the storm; ii) relaying changes to the same communities; and iii) garnering and maintaining community support for, and confidence in, the predictive capacity and utility of storm event forecasting. The low lying, flat topography of Bangladesh means that small changes in tidal surges have huge impacts on significant numbers of people. Therefore the need for timely and accurate predictions is crucial to reduce damage and loss of life. It is hoped that these improvements will eventually occur via incremental advancements in various aspects of weather forecasting and the considerable investment that occurs in Bangladesh in relation to forecasting.
- Communities, whilst recognizing the value of weather forecasts, communicated the limitations of the forecasting from their perspectives. The shortcomings they identified included lack of information about floods in particular, general lack of accuracy (not sufficiently accurate to make informed decisions about farming), operating at too coarse a spatial scale (not sufficiently local to make decisions) and either being too long-term or seasonal (long term forecasts lacking accuracy). These criticisms seem at odds with the conclusion (above) that Bangladesh's weather forecasting systems are state-of-the–art. However, they may well reflect three important factors in relation to weather forecasting in rural Bangladesh:
  1. The communities have a general misunderstanding (and overestimation) of how accurate and timely weather forecasts and extreme event forecasts can be. This leads community members to expect long-term seasonal forecasts that have comparable accuracy (spatially and temporally) to short-term weekly or daily forecasts.
  2. Communities also lack understanding of the complexity and multifactor aspect of floods, including level of siltation of rivers, drainage possibilities, topography of the village, making them extremely difficult to predict.

3. Communities lack understanding of the information provided in forecasts, and therefore are unwilling to react to it. This latter point is very much related to dissemination (see following section), but implies that communication content as well as conduit needs to be addressed.

4.2 Weather and extreme event information dissemination

- Dissemination of information contained in forecasts is another area that Bangladesh authorities and relevant institutions have invested in for many years. Mechanisms for dissemination are extremely varied (e.g. newspapers, radio, television, loud hailer broadcasts in villages) and embrace new technology and favored communications avenues (e.g. cell telephone SMS). Mechanisms and processes for dissemination also appear to be systematic and involve many authorities and institutions, from the national to the local scale. On this basis, the dissemination of forecasts would appear to be largely effective in many cases. This has particularly been the case since apparent failures in effective, comprehensive and timely dissemination in the past have potentially contributed to loss of life and property.
- There are some identified shortcomings in terms of dissemination that should ideally be addressed. These include: i) improved data sharing (with other neighboring countries, for instance) could improve predictive capacity and timeliness of communications; ii) there are risks with broadcasting an underestimation of storm's severity; iii) conveying and communicating the limitations of forecasting (particularly long-term seasonal forecasts for farmers) would moderate community expectations of forecasting capability; iv) forecasts tend to be of a one-size-fits-all approach in terms of content—better tailoring messages to particular requirements and characteristics of end-users may improve their usefulness and uptake; v) with increasing reliance on mobile phones (and smart phone apps) for communication in rural communities, authorities responsible for forecast dissemination should consider how to delivery timely warnings in areas outside of present mobile phone coverage and how to deliver warnings to those at sea (e.g. short wave radio).
- Community responses to, and perceptions of, forecasts and severe weather warnings have been mixed. In many cases, communities reported that forecasts were insufficiently accurate, or that they did not receive them at all (e.g. dichotomy of communities saying no provision of seasonal forecasts, and yet BDM provide regular seasonal forecasts). Authorities and institutions responsible for disseminating forecasts and weather warnings need to take account of some of the identified obstacles to community uptake. These include: i) insufficient understanding of cyclone warnings; ii) a high degree of fatalism and reliance on religious intervention among communities; iii) reliance on traditional methods of forecasting. Other potential issues include: i) a possible community perception of authorities 'crying wolf', where warnings have been broadcast, evasive action was taken and the severe storm did not eventuate in that particular area; ii) the considerable risk of theft of goods and land when abandoning one's property during a storm (community members effectively having to weigh the risk of a predicted storm against the risk of theft); iii) the lack of management of storm shelters in some cases, rendering them risky places to frequent in the event of a storm (for women this may present a particularly perilous risk, with evidence of violence towards women occurring in flood shelters during storm events) (Nasreen 2010).

4.3 Recommendations for CCAFS and WorldFish involvement/investment

- The area of forecasting in Bangladesh is driven by a number of factors, including: i) technological advancements in predictive capacity, modeling software, statistical techniques, etc.; ii) government and donor investment in improving forecasting and driving innovation and implementation; iii) pressure in relation to vulnerability of communities to extreme weather events; and iv) anticipated increase in frequency and severity of extreme weather events attributed to anthropogenic climate change. As such, there is a saturation of activity in this area, often associated with extremely well-funded organizations and donors. Consequently, it is presently difficult to see: i) where CCAFS and/or WorldFish would carve out a niche for themselves in an already crowded market place; and ii) how relatively modest levels of funding (compared with some of the vast investment in this area) would best be applied to advancements that already have considerable institutional momentum.
- In terms of dissemination, again, this is a rapidly advancing area with a great deal of investment, particularly at the national scale. As with forecasting, it is an area where it is difficult to determine exactly where CCAFS/WorldFish would invest, in a manner that wasn't duplicating or competing with previous or existing efforts or activities.
- One possible area that could be suitable/advantageous for CCAFS/WorldFish would be further exploration of the apparent ambiguities and anomalies that exist between what institutions and authorities provide (in terms of forecasting, but particularly in terms of dissemination and communications) and what communities say they receive and require. This is particularly in relation to tailoring dissemination and communication of forecasts to the specific requirements and characteristics of a given community.

Annex 1—Weather data from Chandipur

Daily weather forecasts are available to the community members in Chandipur, and are well utilized. For instance, women and girls use the radio weather forecast to determine when to collect water, whilst 60% of men use the forecast in relation to agricultural planting and fishing (Chaudhury et al. 2012). However, the same authors indicate that younger men are less inclined to use the daily forecast to inform farming, as they are generally less involved in agriculture. However, younger men do use the forecast to obtain information relating to predicted extreme weather events, such as storms.

Weather forecasts are generally disseminated via radio broadcasts, but are also transmitted by announcements in public areas. For men this may be tea stalls and for women this may be at water harvesting points. However, Chaudhury et al. (2012) describe a gender disparity in information exchange, in that younger women and girls are less likely to receive weather information through direct announcements, as their movements are more socially restricted. As mobile phone coverage improves and mobile phone ownership becomes more ubiquitous, SMS weather reports are also becoming more common. Despite these advances, there is still a mistrust regarding the accuracy of weather forecasts, and a persistence in using indigenous knowledge to forecast forthcoming weather events.

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