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Evaluating the Climate Change and Flood Risk and its Counter Measures in Bangladesh

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Abstract

Bangladesh is one of the most climate change vulnerable countries in the globe. The effects of climate change induced disasters like flood, cyclone, sea level rise, heat wave, and drought are becoming visible more prominently. The purpose of this paper is to investigate the risk of climate change induced flood and its existing counter measures adopted by the country. Employing literature survey risks of climate change induced flood, preparation and counter measures against flood damages has been evaluated. Findings indicate frequent occurrence of flood results large scale damage. A number of structural e.g. embankments, polders, submersible embankment, and non-structural measures e.g. flood forecasting and warning, information dissemination, vulnerability ranking, preparatory studies for adaptation against sea level rise, emergency food supply have been adopted by the government to cope up with flood risks. Analyzing government initiatives and local community's indigenous efforts, some measures have been suggested to make flood risks adaption more efficient.

1. Introduction

Bangladesh is identified as one of the most disaster prone countries in the world due to the effects of climate change (Ali, 2013). It is considered to be the country most overstated by climate change and the risk is inflaming for main hydrometeorological disaster to occur (Islam, 2013).The geographical location of this country makes it more prone to various disasters, including floods, cyclone, and earthquakes. Flood of different magnitudes and types occurs every year due to its unique geographical location and topography. Three extended rivers systems like Ganges, Brahmaputra, and Meghna covering a combined total catchments area of about 1.7 million sq. km. extending over China, India, Bhutan, and Nepal flow through this country (HCTT, 2018). Out of these huge catchments only 7% lies in Bangladesh, therefore, has to drain out runoff of an area which is 12 times larger than its size. The residual 93% are distributed over China, India, Nepal, and Bhutan. Outside Bangladesh, 1,360,000 million m^3 of discharge originate annually. About 85% of this discharge is generated between June-October (HCTT, 2018 and DDM, 2014).

Researchers are attracted by the phenomena of global hydrological changes boost up by climate change. They anticipated that frequency of flood occurrence will be increased by the extended river discharge because of intensified precipitation and decreased evapotranspiration (Hirabayashi Y, 2008).The monsoon rainfall in the large catchments of Ganga, Brahmaputra and Meghna basins and ice melting with monsoon rain in Himalaya resulted heavy rainfall causes floods in Bangladesh (Islam, 1995). Bangladesh is being considered one of the most vulnerable countries to climate change (Harmeling

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and Eckstein, 2013).One study predicts that if the current emission rate continue, Bangladesh by 2030 will be 0.54 to 2.16^{0}C warmer (USAID, 2015). Besides, due to climate change, the average monsoon rainfall will be increased by 16-19.5% by 2030 (USAID, 2015). In such situation, Bangladesh is facing accumulated proclivity of the flood. About 60% landmass of the country is situated less than 6m above the sea level. Thereby, flood submerges 30% to 68% area of the country frequently (DDM, 2014). Substantial loss to settlements, public infrastructures, agriculture, and livelihood would be accelerated by the changes in climatic factors and intense flood. This paper, therefore, attempts to evaluate the risks of flood, climate change issues, and the adequacy of counter measures against flood.

2. Methodology

This paper primarily depends on literature survey and content analysis. Information on climate change, flood history, risks, and counter measures against flood has been gathered from relevant journal articles, reports of Bangladesh Water Development Board (BWDB), Japanese International Co-operation Agency (JICA), and Department of Disaster Management (DDM).Bangladesh Climate Change Strategy and Action Plan (BCCSAP) has been reviewed to identify priority program actions adopted by the government. Organizational set up and their responsibilities have been analyzed from the report of Department of Disaster Management (DDM). All the collected data and information have been analyzed carefully to identify climate change risk and ways to combat with such risks. Finally, some planning measures have been suggested to adapt the risks of flood more effectively by evaluating climate change, flood risks, and counter measures against flood.

3. History of Flood in Bangladesh

Bangladesh possesses a long history of flood events (Table 1). Overall, the usual river floods affect roughly 20% of the country and in extreme years increased up to 68%. Major flood prone areas and flood scenario is briefly presented in Figure 4 and Figure 2 respectively.

Table 1. Flood Events History

Year	Flood Affected Area		Year	Flood Affected Area		Year	Flood Affected Area	
	Area (km^2)	Area (%)		Area (km^2)	Area (%)		Area (km^2)	Area (%)
1954	36,800	25	1975	16,600	11	1995	32,000	22
1955	50,500	34	1976	28,300	19	1996	35,800	24
1956	35,400	24	1977	12,500	8	**1998**	**1,00,250**	**68**
1960	28,400	19	1978	10,800	7	1999	32,000	22
1961	28,800	20	1980	33,000	22	2000	35,700	24
1962	37,200	25	1982	3,140	2	2001	4,000	2.8
1963	43,100	29	1983	11,100	7.5	2002	15,000	10
1964	31,000	21	1984	28,200	19	2003	21,500	14
1965	28,400	19	1985	11,400	8	**2004**	**55,000**	**38**
1966	33,400	23	1986	6,600	4	2005	17,850	12

Year	Flood Affected Area		Year	Flood Affected Area		Year	Flood Affected Area	
	Area (km²)	Area (%)		Area (km²)	Area (%)		Area (km²)	Area (%)
1967	25,700	17	**1987**	**57,300**	**39**	2006	16,175	11
1968	37,200	25	**1988**	**89,970**	**61**	**2007**	**62,300**	**42.21**
1969	41,400	28	1989	6,100	4	2008	33,655	22.80
1970	42,400	29	1990	3,500	2.4	2009	28,593	19
1971	36,300	25	1991	28,600	19	2010	26,530	18
1972	20,800	14	1992	2,000	1.4	2011	29,800	20
1973	29,800	20	1993	28,742	20	2012	17,700	12
1974	**52,600**	**36**	1994	419	0.2	2013	15,650	10.6

Source: DDM, 2014

Flood history of Bangladesh indicates that two massive floods occurred in 1988 and 1998 when 61% and 68% area of the country were inundated respectively. Correspondingly 45 and 31 million people were affected by those flood events. Another major flood returned in 2007 affected 13.3 million people by inundating nearly 43% of the country.

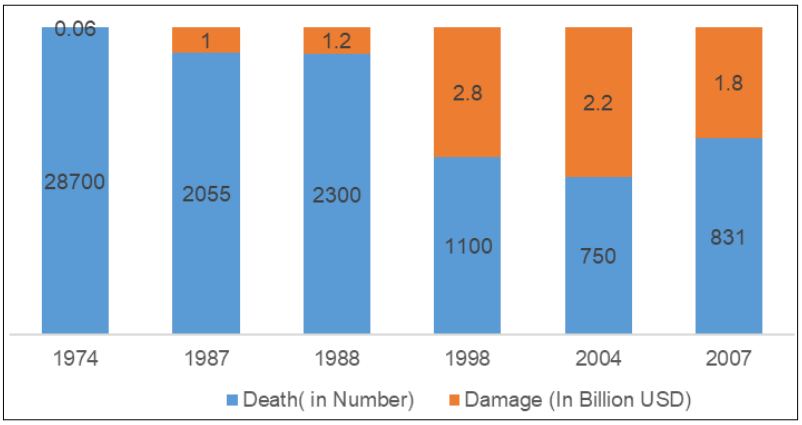


Figure 1. Impacts of Some Notable Flood

Figure 1 indicates that the number of deaths has been decreased while the amount of damage increased due to flood over the years. Different initiatives taken by the government, preparedness, quick response and increased level of awareness reduce the number of deaths. However, change in frequency and characteristics of flood, poor planning, design and implementation of structural measures intensify the damage.

4. Countermeasures against Flood

To encounter flood damages, Bangladesh adopt different types of structural and non-structural measures.

4.1. Structural Measures

The flood control structural measures (Figure 2) generally used in Bangladesh are:

(1) Flood embankments along the river which are constructed in the form of roads and railways,

(2) Submersible flood embankment,

(3) Polders with drainage regulators,

(4) Polders with pump irrigation and drainage,

(5) Gravity irrigation projects with pumping stations along the major rivers.

(6) River Management: River maintenance through dredging is expensive and there is limited effort to control river erosion, particularly on medium and small rivers.

Figure 2. Embankment, Submersible Embankment and Polder

But the flood control initiatives practiced in Bangladesh faces different technical problems (Figure 3) which are as follows:

- Embankment breaching because of riverbank erosion,
- Inadequate planning, design, and construction,
- Limited effort in operation and irregular maintenance,
- Construction of embankment with less compacted and poor soil material,
- Unauthorized embankment breaching during floods.

Figure 3. Embankment Breaching, Poor Construction, Operation and Maintenance

A previous study reported that more than 50% of the embankments (15 out of 25) were failed due to breaching, seepage and sliding, overflow, erosion and cutting by the public.

In addition, the problems related to the efficiency of the embankments, the embankments themselves are imposing problems at different places, such as, riverbed sedimentation, water logging, deterioration of soil productivity, decline in fishery and wildlife habitats, particularly due to FCD projects (Dewan, Nishigaki and Komatsu, 2003).

4.2. Non-Structural Measures

- **Flood forecasting and warning**

  Flood forecasting is difficult in Bangladesh since an extensive volume of data is required in order to operate the hydrological models. The real time hydrological data is collected from 94 Water Level (WL) stations and 70 rainfall stations by Single Site Band (SSB) wireless, fixed and mobile telephone. WL for non-tidal stations are collected five (05) times daily at 3 hourly intervals during day time (6:00 AM to 6:00 PM), and for tidal stations collected hourly. Rainfall is collected everyday starting at 9 AM. Limited WL, rainfall and forecasts of upper catchments from Indian stations are also collected using internet, and e-mail. Furthermore, a dedicated land line radar link with Bangladesh Meteorological Department (BMD) provided frequent (5 minute's interval) rainfall information. Using these data 5 days (24, 48, 72, 96 & 120 hrs) deterministic flood forecast with hydrograph are prepared.

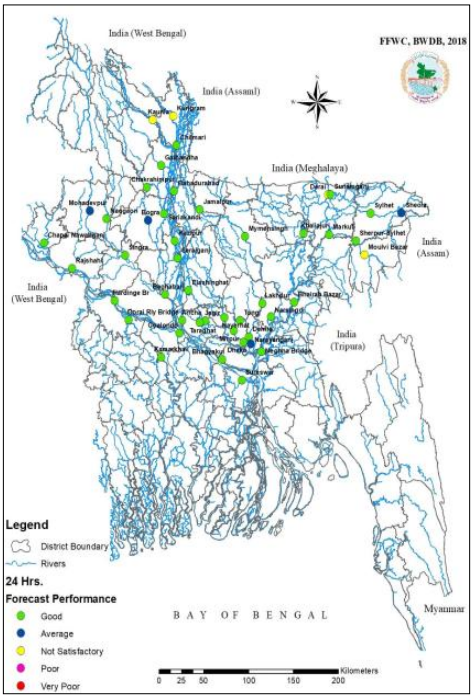


Figure 4. 24 Hrs Forecast Evaluation

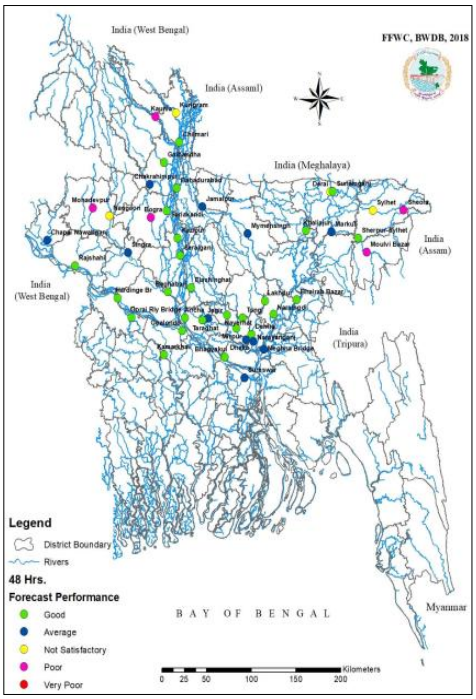


Figure 5. 48Hrs Forecast Evaluation

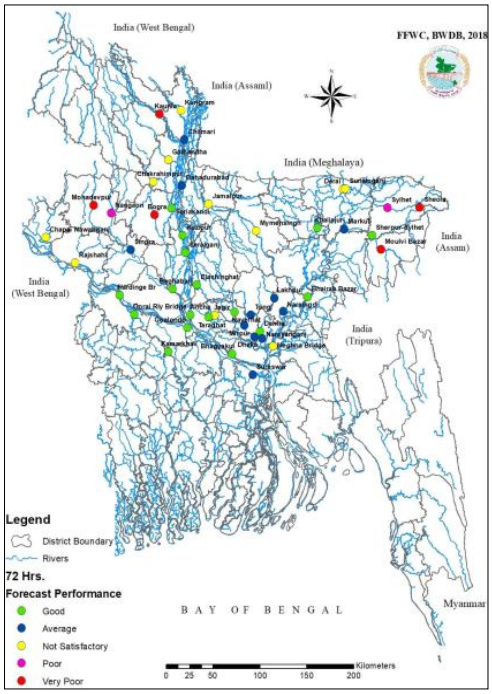


Figure 6. 72 Hrs Forecast Evaluation

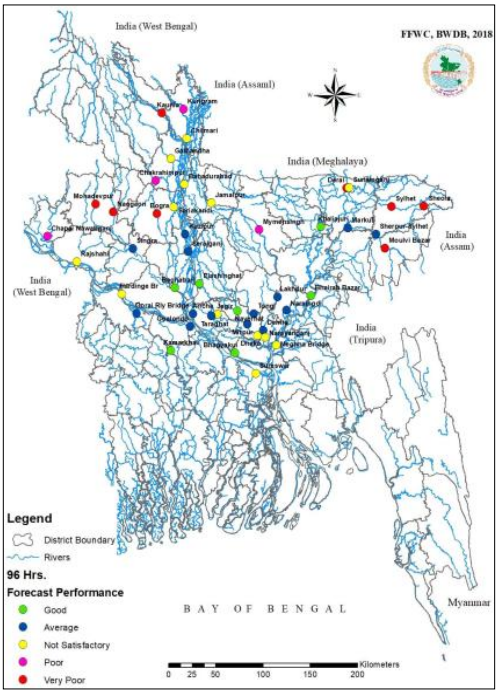


Figure 7. 96Hrs Forecast Evaluation

Figure 4 to 8 shows the quality of flood forecasting for different time intervals. For 1-day forecast 91% stations are between Good and Average, whereas 2-days, 3-days, 4-days and 5-days forecast (80%,61%, 46% and 24%, respectively) stations are between Good and Average. This indicates that forecast quality deteriorates as the period of forecasting become longer. Dissemination of meteorological or flood forecasts to help speedy evacuation. Major modes of dissemination are e-mail, website, print and electronic media, telephone, fax, lobby display, Interactive Voice Response (IVR) through mobile phone.

- **Flood cum Cyclone Shelter**

  Constructed school buildings are used as flood-cum cyclone shelter in

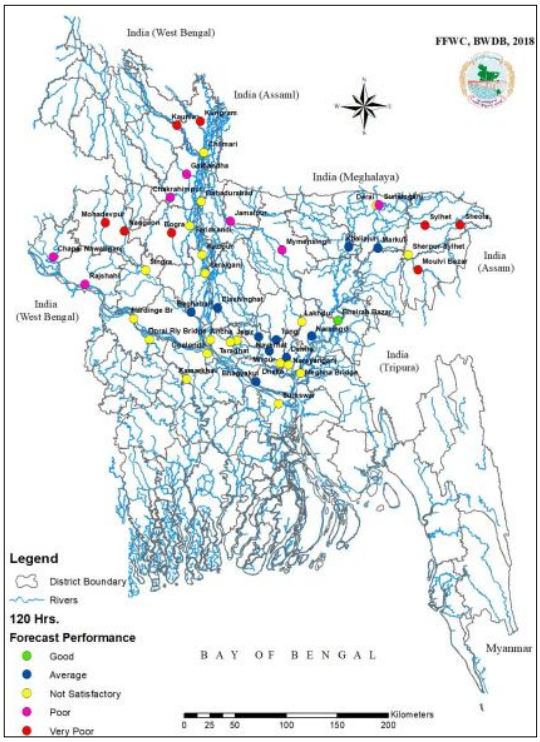


Figure 8. 120Hrs Forecast Evaluation

the coastal zone (Figure 9) with highest risk of flood and storm surge. These school buildings are not changed due to the flood regime, and considered as non-structural measures of flood management.

Figure 9: Distribution of Flood Shelter

- Disaster relief during and post flood situation forms an important part of flood loss recovery

4.3. Organizations Engaged in Flood Management

Several organizations are working in flood management in varying aspects. The major responsibilities of these organizations are presented in Table 2.

Table 2. Organizations and their Responsibilities in Flood Management

Organization	Responsibilities
Water Resources Planning Organization (WARPO)	▪ Macro planning of water resources, ▪ Monitoring and implementation of the National Water Management Plan (NWMP) and its impact, ▪ Assessment of water resources maintenance, ▪ Maintenance, up gradation, and dissemination of the National Water Resources Database (NWRD) and Management Information System
Bangladesh Water Development Board (BWDB)	▪ Conducting Feasibility Studies, project implementation, Operation and Maintenance of Flood Management Projects, ▪ Real Time Data collection for forecasting Flood and Warning Services, Flood information dissemination at national and regional levels
Local Government Engineering Department (LGED)	▪ Operation and maintenance of Small-Scale Flood Control Development (FCD) projects, ▪ Keep up local level infrastructures damage database.
Joint River Commission (JRC)	▪ For trans-boundary rivers, negotiating for data and information exchange.
Bangladesh Meteorological Department (BMD)	▪ Forecasting weather and information dissemination in the Long, medium, and short-term.
Flood Forecasting and Warning Center (FFWC)	▪ Monitoring of 56 rainfall stations, and 86 representative water level stations throughout the country. ▪ Preparing daily statistical and descriptive flood bulletin, forecast for 24, 48 and 72 hours at 52 monitoring points, ▪ Preparation of Upazila Status Map, Satellite Imageries, special flood report during the monsoon season.
Disaster Management Bureau (DMB)	▪ Dissemination information on natural disaster at the community level, and awareness building for Flood Preparedness
Directorate of Relief	▪ Relief and Rehabilitation programs operated in flood affected areas
Local Government Institutions (LGI)	▪ Implementation, Operation and Maintenance of small-scale flood management project, ▪ Dissemination of Flood Information ▪ Relief and Rehabilitation for flood affected people
Non-Government Organizations (NGO)	▪ Flood management advocacy ▪ Relief and Rehabilitation programs for the flood affected people
Institute of Water Modelling (IWM)	▪ Assessment of Flood risk and damage ▪ Mapping of flood affected areas ▪ Forecasting real-time flood and operational water management systems

Source: DDM, 2014

5. Climate Change and Possible Adaptation Measures

The frequency and magnitude of flooding in Bangladesh is influenced by climate change. The rising sea level will hinder the drainage discharged from the rivers to the sea and thus intensify the effect of tidal surges. Deforestation in hill catchment areas causes fast and large scale runoff, and thereby flooding has been intensified. The floodwater drainage into the sea is impeded by the springtides of the Bay of Bengal and thus increase the local monsoon flooding. The mean sea level has been raised during the monsoon. The drainage system has also been affected during monsoon and raise the flood level along the coastal areas. The annual relative sea level rise at locality is 7 millimeter near the coastal areas. The backflow effect generated by the sea level rise can result in more flooding of land from "piled up" river water inland. This undoubtedly seems to be one of the causes for the intensification in flood events (DDM, 2014).Possible adaptation and mitigation measures against climate change induced flooding are stated in the following sections.

5.1. National Policy Context

Bangladesh Climate Change Strategy and Action Plan (BCCSAP) was formulated in 2009 to address the possible impacts of climate change. Table 3 provides a summary of the most relevant action programs to climate change adaptation and mitigation.

Table 3. Adaptation Programs of Actions Prescribed in the BCCSAP

Pillars	Programs of Actions
Food security, social protection, and health	▪ Strengthening institutional capacity for research on climate-resilience ▪ Developing a climate-resilient cropping systems and production technologies e.g. agricultural research for crops tolerant to floods, droughts, and salinity ▪ Adaptation in fisheries sector ▪ Adaptation in livestock sector ▪ Livelihood protection of vulnerable socio-economic groups(including women)
Comprehensive disaster management	▪ Developing flood forecasting and early warning ▪ Awareness raising and mass education toward climate resilience ▪ Developing risk management system for loss of income and property
Infrastructure	▪ Repair and maintenance of existing flood embankments ▪ Repair and maintenance of existing coastal polders ▪ Improvement of existing urban drainage system ▪ Adaptation against floods ▪ Planning and design for river embankments and erosion control management ▪ Planning, design, and implementation of resuscitation of rivers and canals by dredging and de-siltation work
Research and knowledge management	▪ Establish a center for knowledge sharing and training on climate change ▪ Climate change modelling at national and sub-national levels

Pillars	Programs of Actions
	▪ Preparatory studies for adaptation against sea level rise
Capacity building and institutional strengthening	▪ Mainstreaming climate change in national, sectoral, and spatial development programs ▪ Inclusion of climate change in different tiers of government, private sector, civil society, and communities ▪ Consolidating human resource capacity ▪ Integrating gender issues in climate change management ▪ Strengthening institutional capacity for climate change Management ▪ Mainstreaming climate change issues in the electronic, print, and social media

Source: Zamudio and Parry, 2016

5.2. Indigenous Adaptation Measures

A number of indigenous adaptation mechanisms practiced in the flood-prone areas. These local practices represent interaction between humans and nature. These measures are presented as follows:

- Local communities raise the plinths of houses (Figure 10), and cattle sheds. They construct toilets (Figure 12) on raised ground for flooding during the wet season. Homestead gardening (Figure 11) is practiced on the raised plinth.

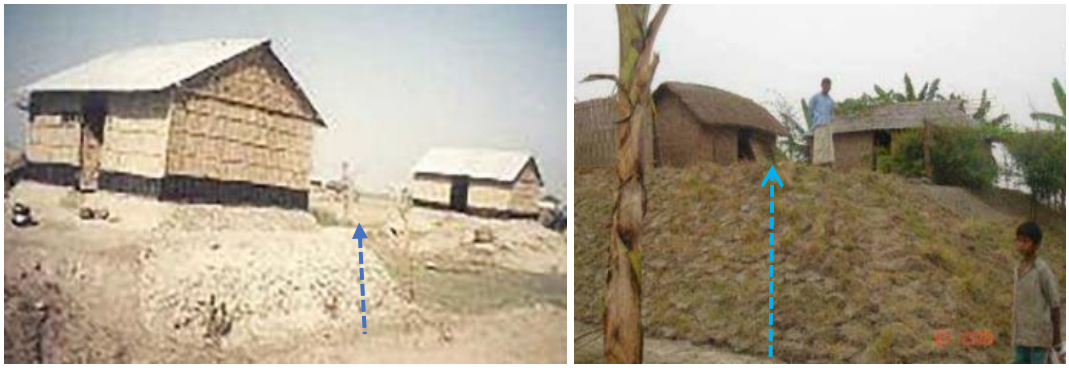


Figure 10. Raised Plinth Height

Figure 11. Homestead Garden on Raised Plinth

Figure 12. Toilet on Raised Plinth

- By using strong bamboo or other wooden planks, they repair and strengthen houses. They make the thatched walls of their houses stronger, and plant trees around their houses to protect from soil erosion.
- Storage of emergency provisions for survival, including dry food, drinking water, fodder, seeds, firewood.

Figure 13. Adapted Place for Livestock

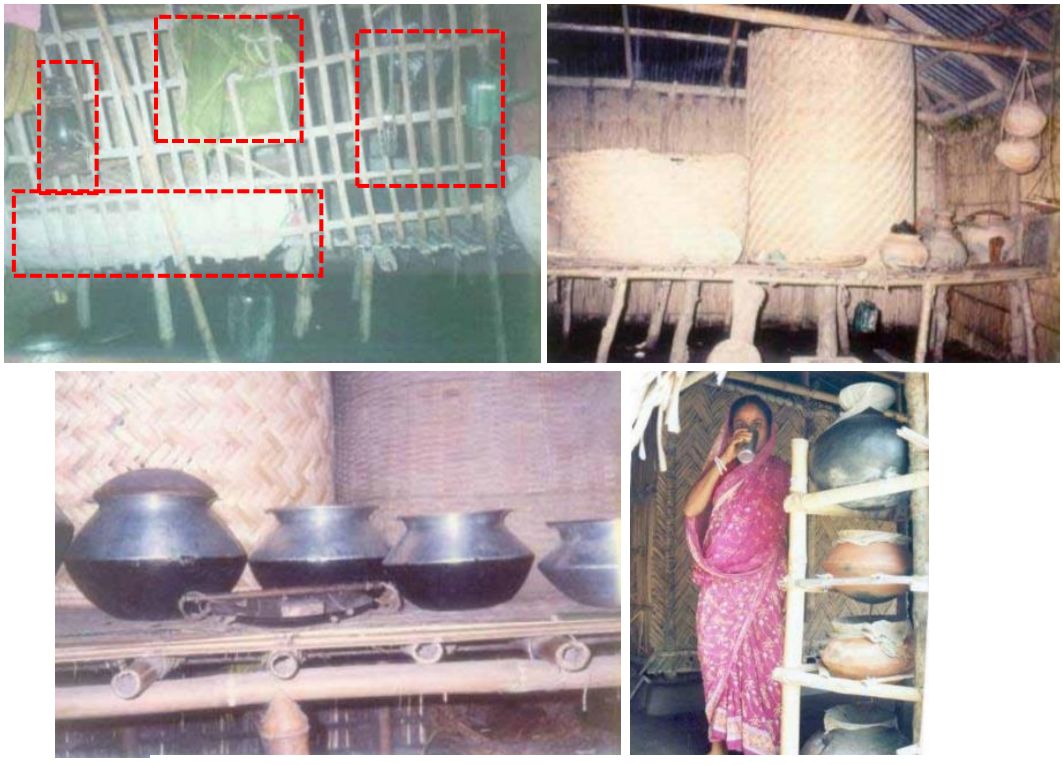


Figure 14. Storage of Safe Drinking Water, Dry Food and Emergency

- Rainwater harvesting at individual and community level (Figure 15 and 16).

Figure 15. Community Level Rainwater Harvesting

Figure 16. Individual Rainwater Harvesting

- Raised Tube well and Pond Sand Filter (Figure 17 and 18).

Figure 17. Raised Tube well

Figure 18. Pond Sand Filter

- Storing portable earthen stoves and saving income generating activities

Figure 19. Storing Extra Furnace and Protecting Income Generating Activities

- Other indigenous adaptation techniques include use of rafts, which is common for people to use rafts made of banana-tree trunks for displacement, such as, over inundated roads (Figure 20).

Figure 20. Commuting during Flood

- Floating cultivation practices for fast growing vegetables or agricultural production (Figure 21), with the whole cycle of planting and cropping linked to the rise and fall of rivers.

Figure 21. Floating Cultivation

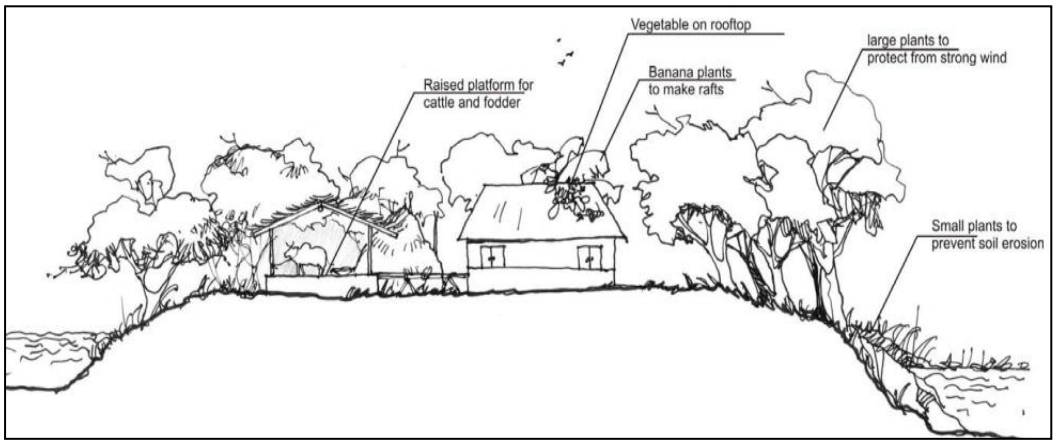
- Cultivation of saline tolerant rice in the tidal flood affected areas and practice of crab culture in saline water.

Figure 22. Saline Tolerant Rice Cultivation

Figure 23. Crab Culture

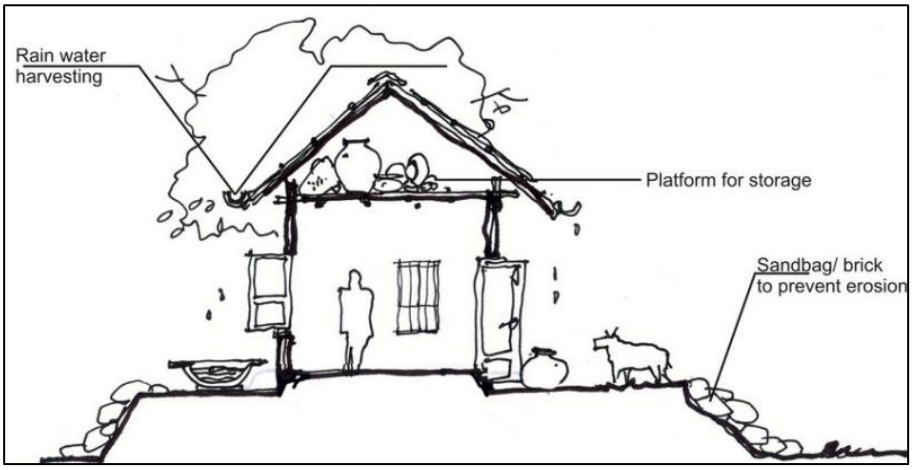
5.3. Design Considerations

Situations where a homestead performs the role of a flood shelter, the main purpose is to raise the homestead above flood level, which is usually achieved by placing the living quarters on raised ground. Following design considerations are suggested by the experts.



Source: Rahman and Mallick, 2010

Figure 24. Design Factors to be considered in Homestead Raising,



Source: Rahman and Mallick, 2010

Figure 25. Design Factors to be considered in House Construction

5.4. Other Initiatives

Vulnerability Ranking

District (administrative unit) wise flood vulnerability assessment has been initiated based on the past trend of flood e.g. maximum water level, maximum flow, flood duration and quantify damage in a limited range. The number of people exposed to different risk level can be identified from vulnerability ranking.

Advancement in forecasting

Recently medium range (10-day lead time probability based) flood forecasting to few places (18 points) has been initiated under a FFWC project on experimental basis.

Community Radio

Government licensed 14 community radio stations including, two proposed stations across the country. In disseminating flood disaster early earning messages, medium radius armature radios are the most useful option. It effectively play a facilitating role during disaster. The disaster emergency response to provide information for the local actors response programs i.e. supplying serving life savings logistic, and 4W(Who, Work, Where, When to do), health hazards related (epidemic) information, safeguarding croplands(pushing saline waters back to sea), safer garbage disposal, improving local drainages, perishing died animals.

Rescue boat

Presently 31 active rescue boats with capacity of accommodating 25 to 30 people during flood rescue has been proposed (Figure 26).

Emergency Food

The local supply depot provides 1,000,000 MT food grain for emergency relief and response during disaster. Figure 31 shows the location of Central Supply Depot (CSD) and Silos (Figure 27).

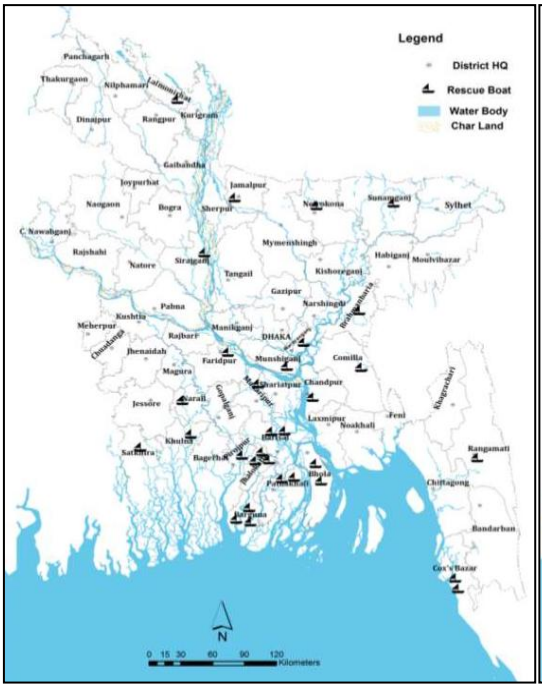


Figure 26. Distribution of Rescue Boat

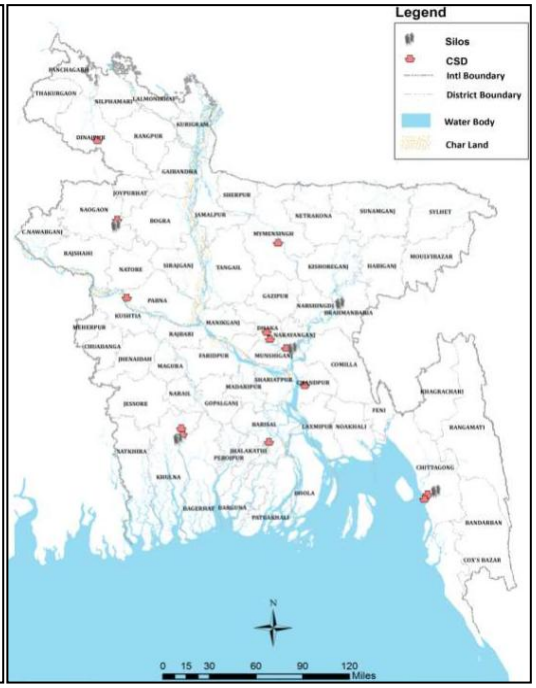


Figure 27. Distribution of CSD and Silos

6. Conclusion

Flood becomes an annual phenomenon for Bangladesh due to its geographical location and topography. Climate change around the globe further worsen the flooding situation. In response different types of structural e.g. dam, embankment and non-structural measures e.g. flood forecasting and warning, emergency rescue, emergency food supply

etc. have been practicing. Though the number of deaths has decreased; the number of people affected, and infrastructural damage increased substantially over the years. Existing structural and non-structural measures should be implemented in a coordinated way depending on the characteristics of flood. More focus should be given on the improvement of long-term forecasting and warning system along with quick dissemination at local level. In addition, crop management, seed bank development, flood insurance, watershed management and strengthening regional and global cooperation are warranted for the mitigation and adaptation of climate change induced flood in Bangladesh.

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