Disaster Risk Reduction
Methods, Approaches and Practices

Rajib Shaw
Fuad Mallick
Aminul Islam
Editors

Climate Change Adaptation Actions in Bangladesh

Springer

Disaster Risk Reduction

Methods, Approaches and Practices

For further volumes:
http://www.springer.com/series/11575

About the Series

Scope of the Series

Disaster risk reduction is a process, which leads to the safety of community and nations. After the 2005 World Conference on Disaster Reduction, held in Kobe, Japan, the Hyogo Framework for Action [HFA] was adopted as a framework of risk reduction. The academic research and higher education in disaster risk reduction has made/is making gradual shift from pure basic research to applied, implementation oriented research. More emphasis is given on the multi-stakeholder collaboration and multi-disciplinary research. Emerging university networks in Asia, Europe, Africa and Americas have urged for the process-oriented research in disaster risk reduction field. Keeping this in mind, this new series will promote the outputs of action research on disaster risk reduction, which will be useful for a wider range of stakeholders including academicians, professionals, practitioners, and students and researchers in the related field. The series will focus on some of emerging needs in the risk reduction field, starting from climate change adaptation, urban ecosystem, coastal risk reduction, education for sustainable development, community based practices, risk communication, human security etc. Through academic review, this series will encourage young researchers and practitioners to analyze field practices, and link it to theory and policies with logic, data and evidences. Thus, the series emphasizes evidence based risk reduction methods, approaches and practices.

Series Editor

Editorial Advisory Group

Rajib Shaw • Fuad Mallick • Aminul Islam
Editors

Climate Change Adaptation Actions in Bangladesh

Springer

Editors
Rajib Shaw
Kyoto University, Kyoto, Japan

Aminul Islam
Sustainable Development
United Nations Development
Programme [UNDP]
Dhaka, Bangladesh

Fuad Mallick
Department of Architecture
BRAC University
Dhaka, Bangladesh

ISSN 2196-4106 ISSN 2196-4114 (electronic)
ISBN 978-4-431-54248-3 ISBN 978-4-431-54249-0 (eBook)
DOI 10.1007/978-4-431-54249-0
Springer Tokyo Heidelberg New York Dordrecht London

Library of Congress Control Number: 2013939616

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Climate change is not a new topic; it is a phenomenon that has been occurring over a period of years. However, the impacts of climate change have become more conspicuous in recent years due to compounded vulnerability—a function of several factors including urbanization, migration, and population pressure, among others. Climate change adaptation has received significant attention over the past 7 or 8 years, and the need for adaptive actions is increasingly highlighted in international, regional, and national forums.

Bangladesh has experienced severe impacts of climate change, especially in coastal regions. Because of their chronic vulnerability, the communities in those areas have developed innovative coping mechanisms for their lifestyles, habitats, and livelihoods. These are evident in case studies and in good practices, set forth in a diversity of documents.

For the last several years, the Comprehensive Disaster Management Program and other environmental and climate-related initiatives have generated a significant knowledge pool, which often has not been linked to higher education. However, several universities in Bangladesh have started master's programs on climate change adaptation and disaster risk reduction. There is an increasing demand for resources that utilize field-based knowledge and for linking those to the curriculum of the master's and diploma programs. With those facts in mind, this book is a modest attempt to compile and analyze some of the existing practices on climate change adaptation.

The contents of this book were developed through a consultation workshop with different universities and related organizations over the past year. The book is one of two volumes prepared for disaster risk reduction and climate change adaptation. Thus, readers are encouraged to look at the contents of the other volume, titled *Disaster Risk Reduction Approaches of Bangladesh*. The editors acknowledge the support of the United Nations Development Programme (UNDP) Dhaka office in this regard. Several eminent authors were able to fulfill their commitments to make contributions in spite of their busy schedules, and we are thankful to all of them. All the statements and opinions in this book are those of the authors and editors, and do not officially represent the organizations to which they belong.

This book is written for students and young researchers aspiring to a career in environmental studies and/or disaster risk reduction. We hope that they will find the book useful and relevant to their work.

Kyoto, Japan
Dhaka, Bangladesh

Rajib Shaw
Fuad Mallick
Aminul Islam

Contents

Part I
Climate Change Impacts

Chapter 1
Climate Change: Global Perspectives

Rajib Shaw, Fuad Mallick, and Aminul Islam

Abstract Climate is changing from its very inception, but the impacts are becoming prominent over last several decades. The trend of temperature change has become more rapid in recent years. Although climate change is a global phenomenon, its consequences will not be evenly distributed. The developing countries will be the first and hardest hit. The impact of climate change will be across the sectors and across nations. Climate change was identified as an urgent global problem that requires governments to unite their efforts to prepare for potential climate risks at the First World Climate Conference in 1979. This recognition led to the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988 to assess the magnitude and timing of changes and estimate their impacts. The United Nations Convention for Climate Change (UNFCCC) entered into force on 21 March 1994. It enjoys near universal membership with 194 Parties (member countries) having ratified. Climate change adaptation is understood as consisting of initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. The term "adaptation" has been used in the climate change community since early 1990s, but no single definition has been generally adopted among conservation professionals. Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR) are broadly understood to be linked in some ways; however, have not yet been taken as a holistically linked complementary set of actions that require collaborative and coordinated action by all concerned stakeholders.

R. Shaw (✉)
Graduate School of Global Environmental Studies, Kyoto University, Kyoto, Japan
e-mail: shaw.rajib.5u@kyoto-u.ac.jp

F. Mallick
BRAC University, Dhaka, Bangladesh

A. Islam
United Nations Development Programme, Dhaka, Bangladesh

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*,
Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_1, © Springer Japan 2013

Keywords Adaptation • Climate change • Disaster risk reduction • IPCC • UNFCCC

1.1 Introduction

The Earth's climate history has experienced a number of changes due to its natural evolution as well as abrupt causes. The temperature, the rainfall and the sea level rise are the indicators for the climate change. The global average air temperature in the twentieth century has increased by 0.6 °C and the 1990s was the hottest decade in the last millennium (IPCC 2001). The temperature in the twentieth century in all continents and oceans had an obvious increasing trend. The standard deviation of the global average temperature was 0.24 °C, the largest difference between two continuous years was 0.29 °C (between 1976 and 1977), and the rate of trend of temperature increase was 0.75 °C, faster than that in any other century in history from the eleventh century to the present. It is noticeable that in the last five decades, from 1956 to 2005, the temperature has increased by 0.64 ± 0.13 °C, twice faster than it did in the twentieth century (IPCC 2001).

It is clear that the trend of temperature change has become more rapid in recent years. There are 11 years in the period from 1995 to 2006 that are classified in the list of 12 years with the highest annual mean global surface air temperature in the history of temperature observation since 1850, of which 1998 and 2005 are the hottest. Five years, from 2001 to 2005, alone have a surface air temperature 0.44 °C higher than the average baseline for the period 1961–1990. During the period 1901–2005, the trend of change in rainfall greatly varied among regions and sub-regions in the same region, as well as during different periods of time in each sub-region. In North America, rainfall has increased in many areas, especially in Northern Canada, while decreasing in the Southwest of the U.S. In South America, precipitation has increased in the Amazon basin and on the Southeastern coast, while it has decreased in Chile and on the Western coast. In Africa, precipitation decreased in South Africa, especially in Sahel, during the period 1960–1980 (IPCC 2007).

In the tropical zone, precipitation decreased in South Asia and West Africa with the trend value of 7.5 % during the period 1901–2005. Australia is the area with the most obvious local features in the trend of precipitation change due to the strong impacts from ENSO. In zones of middle and high latitudes, rainfall has sharply increased in the Central North America, Northeastern America, Northern Europe, Northern Asia and Central Asia. Worldwide, precipitation increased in zones north of the 30° North latitude during the period 1901–2005, while it has decreased in the tropical latitudes since the 1990s. The frequency of heavy rains has increased in many areas, including places where rainfall tends to decrease. The change in rainfall pattern and increasing of temperature caused climate change and it related hazards. Sea level rise is one of those hazards consequences. It is recorded that the average global sea level increased 1.8 mm per year since 1961 and increased of 3.1 mm per year since 1993.

This chapter provides an overview of the global perspective of climate change issues, with specific focus adaptation. The chapter first provides an overview of evolution, followed by impacts of climate change on different sectors. The next few sections provides outline of adaptation and adaptive capacities. Finally, the chapter talks about the link to disaster risk reduction.

1.2 Evolution of Climate Change Issues

Climate change was identified as an urgent global problem that requires governments to unite their efforts to prepare for potential climate risks at the First World Climate Conference in 1979. This recognition led to the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988 to assess the magnitude and timing of changes and estimate their impacts. The IPCC published its First Assessment Report in 1990, which became a basis for negotiations on a climate change convention under the United Nations General Assembly. Between February 1991 and May 1992, the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change met five times under the auspices of the General Assembly, and the Convention text was adopted on 9 May 1992. The Convention was then open for signature at the United Nations Conference on Environment and Development, held in the same year in Rio de Janeiro, Brazil, where 154 states signed. The Convention entered into force on 21 March 1994. It enjoys near universal membership with 194 Parties (member countries) having ratified (UNFCCC 2006).

The Conference of the Parties (COP) to the Convention, the Convention's ultimate authority, held its first session (COP 1) in Berlin, Germany (1995) and launched the "Berlin Mandate" to enable discussion of additional commitments for industrialized countries. Taking into consideration the findings of the IPCC's Second Assessment Report, the Kyoto Protocol to the United Nations Framework Convention on Climate Change (known as the Kyoto Protocol) was adopted at COP 3 (1997) in Kyoto, Japan. The Kyoto Protocol, which entered into force on 16 February 2005, sets individual, legally binding commitment for GHG emissions reduction by Annex I Parties by an average of 5.2 % below 1990 levels, to be achieved between 2008 and 2012. It also established the Adaptation Fund to finance adaptation projects and programs in developing countries that are Parties to the Kyoto Protocol. The primary source of the fund is a share of proceeds from Clean Development Mechanism projected activities (UNFCCC 2007).

1.3 Climate Change Impacts on Different Sectors

The warming of the planet will be gradual, but the effects of extreme weather events will be abrupt and more acutely felt. Although climate change is a global phenomenon, its consequences will not be evenly distributed. The developing countries will be the first and hardest hit. The impact of climate change will be across the sectors and across nations. Some of the key impacts of climate change are summarized below. Climate change is already beginning to transform life on earth. Around the globe, seasons are shifting, temperatures are climbing and sea levels are rising. Climate change will permanently alter the lands and waters we all depend upon for survival. Following brief some of the main impacts of future climate change on systems and sectors (Nguyen 2010):

Ecosystems: For increases in global average temperature exceeding 1.5–2.5 °C and in concomitant atmospheric CO_2 concentrations, major changes are projected in ecosystem structure and function, species' ecological interactions and shifts in species' geographical ranges, with predominantly negative consequences for biodiversity and ecosystem goods and services. Acidification of ocean will have negative impacts on the structure of snails and arcos, etc.

Food Security: Globally, the potential for food production is projected to increase with increases in local average temperature over a range of 1–3 °C, but above this it is projected to decrease. At lower latitudes, especially in seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1–2 °C).

Coastal Areas: Coasts are projected to be exposed to increasing risks, including coastal erosion, due to climate change and sea level rise. The effect will be exacerbated by increasing human-induced pressures on coastal areas. Annually, many millions more people than at present are projected to experience floods every year due to sea level rise. The numbers affected will be largest in the densely populated and low-lying mega deltas of Asia and Africa with small islands being especially vulnerable.

Industry, Settlements and Society: The most vulnerable industries, settlements and societies are generally those in coastal and river flood plains, those whose economies are closely linked with climate-sensitive resources and those in areas prone to extreme weather events. Poor communities can be especially vulnerable, in particular those concentrated in high-risk areas.

Human Health: The health status of millions of people is projected to be affected through, for example, increases in malnutrition; increased deaths, diseases and injury due to extreme weather events; increased burden of diarrheal diseases; increased frequency of cardio-respiratory diseases due to higher concentrations of ground level ozone in urban areas related to climate change; and the altered spatial distribution of some infectious diseases. Climate change is projected to bring some benefits in temperate areas, such as fewer deaths from cold exposure. Overall, however, it is expected that the benefits will be outweighed by the negative health effects of rising temperatures.

Water Resources: Water resources are a key for all sectors and regions for each region and each watershed. Climate change is expected to exacerbate current stresses on water resources from population growth and economic and land-use change, including urbanization. On a regional scale, mountain snow pack, glaciers and small ice caps play a crucial role in freshwater availability. Widespread mass losses from glaciers and reductions in snow cover over recent decades are projected to accelerate. Changes in precipitation and temperature lead to changes in runoff and water availability. Runoff is projected with high confidence to increase by 10–40 % by the middle of the century at higher latitudes and in some wet tropical areas, including populous areas in East and South-East Asia, and decrease by 10–30 % over some arid regions at mid-latitudes and arid and semi-arid tropics, due to decreases in rainfall and higher rates of evaporate transpiration.

Drought-affected areas are projected to increase in extent, with the potential for adverse impacts on multiple sectors, such as agriculture, water supply, energy production and health. It is likely that up to 20 % of the world population will live in areas where river flood potential could increase by the 2080s. Increases in the frequency and severity of floods and droughts are projected to adversely affect sustainable development. Increased temperatures will further affect the physical, chemical and biological properties of freshwater lakes and rivers, with predominantly adverse impacts on many individual freshwater species, community composition and water quality. In coastal areas, sea level rise will exacerbate water resource constraints due to increased salinization of groundwater supplies.

1.4 Adaptation to Climate Change

Climate change adaptation is understood as consisting of initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. The term "adaptation" has been used in the climate change community since early 1990s, but no single definition has been generally adopted among conservation professionals. Most definitions offered in the literature in some way reflect that climate change adaptation involves "initiatives and measures designed to reduce the vulnerability of natural and human systems against actual or expected climate change effects." However, the term adaptation is not yet well-understood by the general public in the context of climate change. In part the term has engendered confusion because the same word refers to the process by which organisms naturally adapt over time to survive in a new environment, even though the rapid rate of climate change is expected to outpace the capacity of many organisms to adapt in this classical sense (Denevan 1983).

In an issue of Nature in 2007, a team of science policy experts argue that adapting to climate change would be a more effective means of dealing with global warming than reducing emissions of greenhouse gases. It is mentioned that temperatures are rising on Earth, which is heating up the debate over global warming and the future of our planet, but what may be needed most to combat global warming is a greater focus on adapting to our changing plane. While many consider it taboo, adaptation to global climate change needs to be recognized as just as important as mitigation, or cutting back, of greenhouse gases humans pump into Earth's atmosphere. The science policy experts, writing in the issue of Nature, say adapting to the changing climate by building resilient societies and fostering sustainable development would go further in securing a future for humans on a warming planet than just cutting gas emissions.

Adaptation is adjustment in ecological, social, or economic systems in response to actual climatic stimuli and their effects or impacts (Arizona State University 2007). This term refers to changes in processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate. It involves adjustments to reduce the vulnerability of communities, regions, or activities to climatic change and variability. Adaptation is important in the climate change issue in two ways—one relating to the assessment of impacts and vulnerabilities, the other to the development and evaluation of response options. Comprehending expected adaptations is essential to impact and vulnerability assessment and hence is fundamental to estimating the costs or risks of climate change (Fankhauser 1996; Smit et al. 1999; Pittock and Jones 2000). An article of the United Nations Framework Convention on Climate Change (UNFCCC) refers to "dangerous" human influences on climate in terms of whether they would "allow ecosystems to adapt, ensure food production is not threatened, and enable economic development to proceed in a sustainable manner." The extent to which ecosystems, food supplies, and sustainable development are vulnerable or "in danger" depends on their exposure to climate change effects and on the capacity to adapt. Therefore, to assess the dangerousness of climate change, impact and vulnerability assessments must address the likelihood of autonomous adaptations.

Adaptation is also considered as an important response option or strategy, along with mitigation (Fankhauser 1996; Smith 1996; Pielke 1998; Kane and Shogren 2000). Even with reductions in greenhouse gas (GHG) emissions, global temperatures are expected to increase, other changes in climate—including extremes—are likely, and sea level will continue to rise (Rayner and Malone 1998). Hence, development of planned adaptation strategies to deal with these risks is regarded as a necessary complement to mitigation actions (Burton et al. 1993; Smith et al. 1996; Smit et al. 1999).

The COP at its 13th session in Bali, Indonesia (2007) launched a comprehensive process to enable the full, effective and sustained implementation of the Convention through long-term cooperative action, now, up to and beyond 2012, as contained in Decision 1/CP13 (widely known as the Bali Action Plan) (Kato 2010). Unlike the Kyoto Protocol which heavily focuses on mitigation of GHG emissions, the Bali Action Plan gives equal weight to action on mitigation and adaptation, which are to be supported by finance and technology development and transfer, and achieved under an overarching shared vision for a long term cooperative action under the Convention. The COP established the Ad Hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA), a negotiating body, to consider matters related to the Bali Action Plan. It initially was to complete its work and present an agreed outcome for adoption at COP 15 (2009) in Copenhagen, Denmark. As negotiations on the Bali Action Plan did not conclude at the COP 15, Parties decided to extend its mandate to present the outcome of its work at COP 16 (2010) in Cancun, Mexico (UNFCCC 2009).

The focus for the early phase of the intergovernmental negotiations under the Convention was largely on issues relating to the mitigation of GHGs. It was not until COP 7 (2001) that the consideration of adaptation to climate change made significant progress with the adoption of decision 5/CP.7 which sets guidance for the implementation of Article 4, paragraphs 8 and 9 of the Convention. Decision 5/CP.7 became the cornerstone for much of the subsequent adaptation-related work under the Convention. It also outlines a number of activities to be supported by funding mechanisms under the Convention and the Kyoto Protocol, including those related to DRR such as supporting capacity building for preventive measures, planning, preparedness and management of disasters relating to climate change, including contingency planning in particular for droughts and floods in areas prone to extreme weather events; and strengthening existing and, where needed, establishing national and regional centers and information networks for rapid response to extreme weather events. Decision 5/CP.7 further mandated the consideration of the implementation of insurance-related actions. Of particular importance to the LDCs, decision 5/CP.7 mandated action to enhance capacity of LDCs in dealing with climate change, including the preparation and implementation of national adaptation programs of action (NAPAs) (UNFCCC 2001).

Adaptation to climate change became the central issues at COP 10 (2004) in Buenos Aires, Argentina where Parties, taking into account the outcomes of the activities under decision 5/CP.7, adopted decision 1/CP.10: the Buenos Aires program of work on adaptation and response measures. Under decision 1/CP.10, Parties also agreed to develop a structured five-year program of work on the scientific, technical and socio-economic aspects of impacts, vulnerability and adaptation to climate change, to address the issues of methodologies, data and modeling; vulnerability assessments; adaptation planning, measures and actions; and the integration into sustainable development (UNFCCC 2004). The initial sets of activities were agreed at COP 12 (2006) in Nairobi, Kenya where it was renamed the "Nairobi work program on impacts, vulnerability and adaptation to climate change".

Lastly, a comprehensive adaptation framework/programme that is being considered under the Bali Action Plan to be part of a future climate regime is envisaged to include provisions to integrate adaptation into national and sectoral planning processes, to develop knowledge, information and capacity for implementing concrete adaptation actions, to enhance adaptation technologies, to mobilize the cooperation of relevant organizations, and to monitor and evaluate the support for adaptation action (Kato 2010).

1.5 Adaptive Capacity

Adaptive capacity is the potential or ability of a system, region, or community to adapt to the effects or impacts of climate change. Enhancement of adaptive capacity represents a practical means of coping with changes and uncertainties in climate, including variability and extremes. In this way, enhancement of adaptive capacity reduces vulnerabilities and promotes sustainable development (Smit et al. 1999). Considerable attention has been devoted to the characteristics of communities, countries, and regions that influence their propensity or ability to adapt and hence their vulnerability to risks associated with climate change. These determinants of adaptive capacity relate to the economic, social, institutional, and technological conditions that facilitate or constrain the development and deployment of adaptive measures (Kelly and Adger 2000).

1.5.1 Adaptation Characteristics and Processes

Adaptation refers both to the process of adapting and to the condition of being adapted. The term has specific interpretations in particular disciplines. In ecology, for example, adaptation refers to changes by which an organism or species becomes fitted to its environment (Lawrence 1995); whereas in the social sciences, adaptation refers to adjustments by individuals and the collective behavior of socioeconomic systems. This chapter follows IPCC (2007), and Smit et al. (1999) in a broad interpretation of adaptation to include adjustment in natural or human systems in response to experienced or future climatic conditions or their effects or impacts—which may be beneficial or adverse.

1.5.2 Components and Forms of Adaptation

As both a process and a condition, adaptation is a relative term: It involves an alteration in something (the system of interest, activity, sector, community, or region) to something (the climate related stress or stimulus). Description of an adaptation requires specification of whom or what adapts, the stimulus for which the adaptation is undertaken, and the process and form it takes (Downing et al. 1997).

1.5.3 Climate Stimuli for Adaptation

Most impact and adaptation studies to date have been based on climate change scenarios that provide a limited set of possible future climates—invariably specified as average annual conditions, such as temperature and moisture. Yet the climate change-related stimuli for which adaptations are undertaken (i.e., adaptation to what?) are not limited to changes in average annual conditions; they include variability and associated extremes. Climatic conditions are inherently variable, from year to year and decade to decade. Variability goes along with, and is an integral part of, climate change (Arizona State University 2007): a change in mean conditions actually is experienced through changes in the nature and frequency of particular yearly conditions, including extremes. Thus, adaptation to climate change necessarily includes adaptation to variability (Smit et al. 1999). Downing et al. (1997) and others use the term “climate hazards” to capture those climate stimuli, in addition to changes in annual averages, to which the system of interest is vulnerable. Climate change stimuli are described in terms of “changes in mean climate and climatic hazards,” and adaptation may be warranted when either of these changes has significant consequences (Downing et al. 1997). In water resource management, changes in the recurrence interval of extreme conditions, which are associated with changes in means, are the key stimuli (Pittock and Jones 2000). Natural and human systems have adapted to spatial differences in climate. There also are examples of adaptation (with varying degrees of success) to temporal variations notably, deviations from the annual average conditions on which climate change scenarios focus. Many social and economic systems including agriculture, forestry, settlements, industry, transportation, human health, and water resource management have evolved to accommodate some deviations from “normal” conditions, but rarely the extremes (Leary 1999).

1.6 Adaptation Types and Forms

Adaptations have been distinguished according to individuals’ choice options as well, including “bear losses,” “share losses,” “modify threats,” “prevent effects,” “change use,” and “change location” (Burton et al. 1993; Rayner and Malone 1998). The choice typology has been extended to include the role of community structures, institutional arrangements, and public policies (Downing et al. 1997).

The IPPC report has also clarified two kind of adaptation:

Planned adaptation often is interpreted as the result of a deliberate policy decision on the part of a public agency, based on an awareness that conditions are about to change or have changed and that action is required to minimize losses or benefit from opportunities (Pittock and Jones 2000).

Autonomous adaptations are widely interpreted as initiatives by private actors rather than by governments, usually triggered by market or welfare changes induced by actual or anticipated climate change (Leary 1999). Smith et al. (1996) describe autonomous adaptations as those that occur “naturally,” without interventions by public agencies, whereas planned adaptations are called “intervention strategies.” Thus defined, autonomous and planned adaptations largely correspond with private and public adaptation, respectively.

The extent to which society can rely on or market adaptation to reduce the costs of climate change impacts to an acceptable or no dangerous level is an issue of great interest. Autonomous adaptation forms a baseline against which the need for planned anticipatory adaptation can be evaluated. Poor and landless households have limited resources, yet failure to adapt can lead to significant deprivation, displacement, morbidity, and mortality. Subsistence farmers do not have the same adaptation options as commercial producers. Water supply adaptations may involve landowners, private traders, local authorities, water-dependent businesses, national governments, and international organizations. Each stakeholder has distinct interests, information, risks, and resources and hence would consider distinct types of adaptive responses (Downing et al. 1997).

1.7 Link to Disaster Risk Reduction

Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR), though broadly understood to be linked in some ways, have not yet been taken as a holistically linked complementary set of actions that require collaborative and coordinated action by all concerned stakeholders (Shaw et al. 2010). The significance of CCA–DRR synergy cannot be felt more by vulnerable communities who do not feel the impact of climate change or natural disaster sectorally, but it hits them as a combined whole with devastating effects. It needs to be appreciated that a piecemeal, sectorally split approach to this complex set of problems will not bear fruit. Recent work by researchers and policy makers has thrown light on the intricate linkages between cross sectoral development activities, their impact on the environment, subsequent detrimental impacts of a deteriorating environment on human life, and the integrated approach needed to address this combined threat of climate change and disasters (AUEDM 2010). Such an understanding can be very meaningfully deployed at various levels: from governance to voluntary action to education, and can go a long way in developing community based and environment based resilience to climate change as well as disasters.

Three common issues of CCA and DRR development are: increasing focus on local governments, emphasis on multi-disciplinary approaches, and emphasize theory to practice. The key challenge is how to incorporate the CCA and DRR in the local practices. A comparative analysis of rainfall data analysis and people's perception shows the gap in understanding (Takahashi 2008). While in the area called Kurigram, almost 80 % of the farmers think that rainfall is decreasing, while the fact is that the average annual rainfall is increasing. The reason of this gap can be explained with the local variations. To a farmer, the rainfall is the one which is required for the agriculture purposes. Monthly variation shows that there has been strong change in the monthly rainfall and the effect is that agriculture is affected. To cope with this type of changes, local adjustment in farming practices are essential. The similar approach is required for reducing the impacts of disasters at the local level.

CCA and DRR have its own positive side, issues and challenges (Shaw et al. 2010). CCA and DRR do not overlap exactly. However, there are significant scopes to bring these two sectors together. One of the key differences is that, the DRR approaches are mainly based on past experiences, while CCA is more on the future projections. For example, when a river dyke is made as a risk reduction measure, the deciding factors for the height of the dykes are: past flood levels or rainfall data, and importance of the area (commercial, residential, industrial or agriculture). This has been a traditional approach of DRR. However, the current DRR approach incorporates future possible rainfall in the area (with different levels of uncertainty), in addition to the above factors. This is an example where CCA and DRR overlaps and comes together. Adaptation can be planned (with information on future uncertainty) or autonomous (without focusing on long term future, and planning). Understanding adaptation depends on two key parameters: clarity or uncertainty of existing climate predictions and the vulnerability of a community or household to a given climate related hazard. After examining uncertainty and vulnerability in more detail, the elements of adaptation are considered, with particular emphasis given to the role played by social networks in enabling knowledge sharing, access to resources and influence over policy. The principal adaptation activities are identified as vulnerability reduction, building adaptive capacity and strengthening resilience (Ensor and Berger 2009).

References

Arizona State University (2007) Adaptation to global climate change is an essential response to a warming planet. ScienceDaily

AUEDM (2010) Education-research interface of climate change adaptation and disaster risk reduction. AUEDM report, Kyoto, 33 pp

Burton I, Kates RW, White GF (1993) The environment as hazard. The Guilford Press, New York, p 290

Denevan W (1983) Adaptation, variation and cultural geography. Professional Geographer 35:406–412

Downing TE, Ringius L, Hulme M, Waughray D (1997) Adapting to climate change in Africa. Mitig Adapt Strat Glob Chang 2:19–44

Ensor J, Berger R (2009) Understanding climate change adaptation: lessons from community based approaches. Practical Action, Warwickshire, 192 pp

Fankhauser S (1996) The potential costs of climate change adaptation. In: Smith J et al (eds) Adapting to climate change: an international perspective. Springer, New York, pp 80–96

International Panel on Climate Change (IPCC) (2001) Climate Change 2001: impacts, adaptation and vulnerability. Contribution of Working Group II to the Third Assessment Report. Available at: http://www.grida.no/publications/other/-ipcc_tar/. Cited in May 2010

IPCC (2007) Climate Change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report. Available at: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf. Cited in June 2010

Kane SM, Shogren JF (2000) Linking adaptation and mitigation in climate change policy. Clim Chang 45:75–102

Kato M (2010) Disaster risk reduction under the United Nations Framework convention on Climate Change. In: Shaw R, Pulhin J, Pereira J (eds) Climate change adaptation and disaster risk reduction: issues and challenges. Emerald Publication, Bingley, pp 47–75

Kelly PM, Adger WN (2000) Theory and practice in assessing vulnerability to climate change and facilitating adaptation. Clim Chang 47:325–352

Lawrence E (1995) Henderson dictionary of biological terms. Longman Scientific and Technical, Harlow

Leary NA (1999) A frame work for benefit-cost analysis of adoptation to climate change and climate variability. Mitig Adapt Strat Glob Chang 4(3–4):307–318

Nguyen H (2010) Climate change and drought risk management: study on local adaptation south Central Vietnam. Doctorate Thesis, Kyoto University, 264 pp
Pielke RA (1998) Rethinking the role of adaptation in climate policy. Global Environ Change 8:159–170
Pittock B, Jones RN (2000) Adaptation to what and why? Environ Monit Assess 61:9–35
Rayner S, Malone EL (eds) (1998) Human choice and climate change, vol 3: The tools for policy analysis. Battelle Press, Columbus
Shaw R, Pulhin J, Pereira J (2010) Climate change adaptation and disaster risk reduction: overview of issues and challenges. In: Shaw R, Pulhin J, Pereira J (eds) Climate change adaptation and disaster risk reduction: issues and challenges. Emerald Publication, Bingley, pp 1–19
Smit B, Burton I, Klein RJT, Street R (1999) The science of adaptation: a framework for assessment. Mitig Adapt Strat Glob Chang 4:199–213
Smith K (1996) Environmental hazards: assessing risk and reducing disaster. Routledge, London
Smith JB, Bhatti N, Menzhulin G, Benioff R, Budyko MI, Campos M, Jallow B, Rijsberman F (eds) (1996) Adapting to climate change: an international perspective. Springer, New York
Takahashi F (2008) Understanding community perceptions and needs in relation to climate change and disaster risk reduction: role of NGOs in Bangladesh. Master Thesis, Kyoto University, Kyoto
UNFCCC (2001) Report of the Conference of the Parties on its seventh session, held at Marrakesh from 29 October to 10 November 2001. Addendum. Part two: Action taken by the Conference of the Parties, vol I. United Nations Office, Geneva, pp 32–39. Available at: <http://unfccc.int/resource/docs/cop7/13a01.pdf#page=32> Accessed 14 Nov 2012
UNFCCC (2004) Report of the Conference of the Parties on its tenth session, held at Buenos Aires from 6 to 18 December 2004. Addendum. Part Two: Action taken by the Conference of the Parties at its tenth session. United Nations Office, Geneva, pp 2–6. Available at: <http://unfccc.int/resource/docs/cop10/10a01.pdf#page=2> Accessed 14 Nov 2012
UNFCCC (2006) United Nations framework convention on climate change: handbook. UNFCCC, Bonn
UNFCCC (2007) Uniting on climate. UNFCCC, Bonn
UNFCCC (2009) Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009. Addendum. Part Two: Action taken by the Conference of the Parties at its fifteenth session. United Nations Office, Geneva, p 3. Available at: <http://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf> Accessed 14 Nov 2012

Chapter 2
Climate Change Impacts, Scenario and Vulnerability of Bangladesh

Ainun Nishat and Nandan Mukherjee

Abstract Bangladesh is affected strongly by climate change. Increasing surface air temperature is most prominent in Bangladesh, where an increasing trend and temporal variation in the mean seasonal temperature is observed within the range of 0.4–0.65 °C during the past 40-year period. Although the winter season experiences the minimum rainfall, historical trend is showing a positive inclination in 27 out of 32 rainfall observatories of the meteorological department. The riverine flood (or monsoon flood) is affected by the following climate change related phenomenon, especially due to change in the frequency and intensity in extreme rainfall event may subsequently increase the intensity of flood. Riverbank erosion is one of the major natural disasters of Bangladesh, which is also related to the monsoon flooding. Floods, especially the high intensity floods, often devastate physical infrastructure such as road networks, educational centres, market places, administrative buildings etc. Changes in climate may affect irrigation requirements for all the three cropping seasons: Rabi, Kharif-I, and Kharif-II. At present, western parts of Bangladesh are periodically being affected by droughts in winter months. Since the temperature will rise, and there exists a strong possibility that the winter precipitation will decrease further, it is likely that the moisture content of topsoil would decrease substantially leading to severe moisture stress.

Keywords Agriculture production • Climate change impacts • Flooding • Infrastructure failure • Sea level rise

A. Nishat (✉) • N. Mukherjee
BRAC University, Dhaka, Bangladesh
e-mail: ainunnishat@yahoo.com

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*,
Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_2, © Springer Japan 2013

2.1 Introduction

In recent years, climate change has become a major concern both in the world of development practitioners and in the world of politics. It arises from past and present emissions of greenhouse gases increasing pre-existing concentrations of these gases in the atmosphere. The problem is geopolitical in nature, nor is there any spatial uniformity in the likely impacts of climate change, neither responsibility for climate change nor its likely impacts are equally distributed among countries (Barnett 2007). Now this is a global concern on which key political masters' or political personalities are meeting at global, regional or bilateral level on some thematic agenda seeking for solutions. The political process is complex, as emission from each country evenly dispersed through the atmosphere and doesn't follow any geo-political boundary. The consequences of these emissions will impact on all countries to some degree, irrespective of their contribution in emission and often the poor and developing countries (whose emission contribution is relatively very small) become the worst victim to this change. Bangladesh is no exception to this. The impacts of climate change are felt on different aspects in Bangladesh, starting from temperature, precipitation change, sea level change, and changes in cyclone or tornado intensity, time and path.

In Bangladesh there are four prominent seasons, namely, winter (December to February), Pre-monsoon (March to May), Monsoon (June to early-October), Post-monsoon (late-October to November). In the following sections, observed trend in the climate variability in terms of change in the temperature and rainfall is expressed in seasonal or four equal three-monthly slabs starting from December covering a complete 12 months to November (DJF, MAM, JJA and SON).

This chapter starts with the observed changes in temperature and rainfall. The next part talks about the projections, and reviews past literatures and models. The third part talks about the risks and vulnerability with specific emphasis on hydrological events like flooding, river bank erosion, freshwater demand, future water stress, groundwater recharge, agriculture and transport network.

2.2 Observed climate change in Bangladesh

2.2.1 Temperature

Increasing surface air temperature is most prominent in Bangladesh, where an increasing trend and temporal variation in the mean seasonal temperature is observed within the range of 0.4–0.65 °C during the past 40-year period (1967–2007). Over the past few decades, a warmer winter is being experienced by the country with a prominent increase in the minimum temperature. Similar to this, more hot summer is also experienced during the pre-monsoon and monsoon seasonal months when a prominent rise in the maximum and minimum temperature is observed over the last few decades. A rise in the minimum temperature by 0.45 °C and 0.52 °C is observed during the winter (DJF) and monsoon (JJA) season

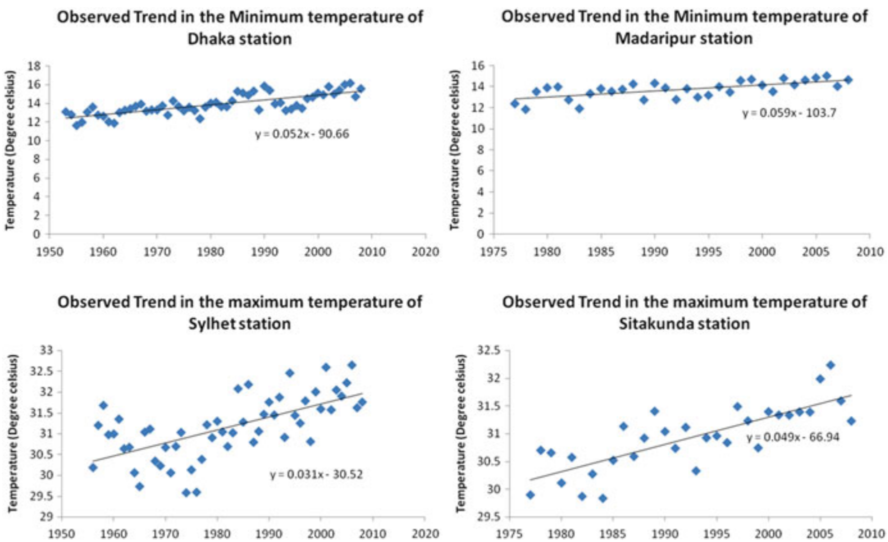


Fig. 2.1 Observed trend in minimum and maximum temperature in selected stations. *Source*: Author's calculation

respectively. Maximum temperature is also observed to be increased during the pre-monsoon (MAM) and post-monsoon (JJA) month by 0.87 °C and 0.42 °C respectively. Rise in the minimum temperature during the winter season (DJF) is observed in 25 out of 34 climate observatories of the Bangladesh Meteorological Department (BMD), where it is prominent in Dhaka (0.05 °C/year), Chuadanga (0.05 °C/year), Madaripur (0.06 °C/year) and Syedpur (0.08 °C/year) stations. Rise in the maximum temperature during the hot summer months of JJA is observed in almost all the stations (except Rangpur), where it is prominently observed in the range of 0.03–0.05 °C/year in Saydpur, Sitakunda, Sylhet and in Tangail station (Fig. 2.1).

2.2.2 *Rainfall*

In Bangladesh, monsoon is both hot and humid, brings heavy torrential rainfall throughout the season. About four-fifths of the mean annual rainfall occurs during monsoon. Warm conditions generally prevail throughout the season, although cooler days are also observed during and following heavy downpours. Post-monsoon is a short-living season characterized by withdrawal of rainfall and gradual lowering of night time minimum temperature. Mean annual rainfall is about 2,347 mm, which varies within the range of 1,640–2,831 mm. Increase in the seasonal rainfall is expected to be caused by the climate variability mainly for increase in the seasonal temperature. Observed seasonal trend in rainfall statistics from the BMD stations over the last few decades is elaborated below. In Bangladesh, in all the seasons there is observed an overall increase in the mean seasonal rainfall,

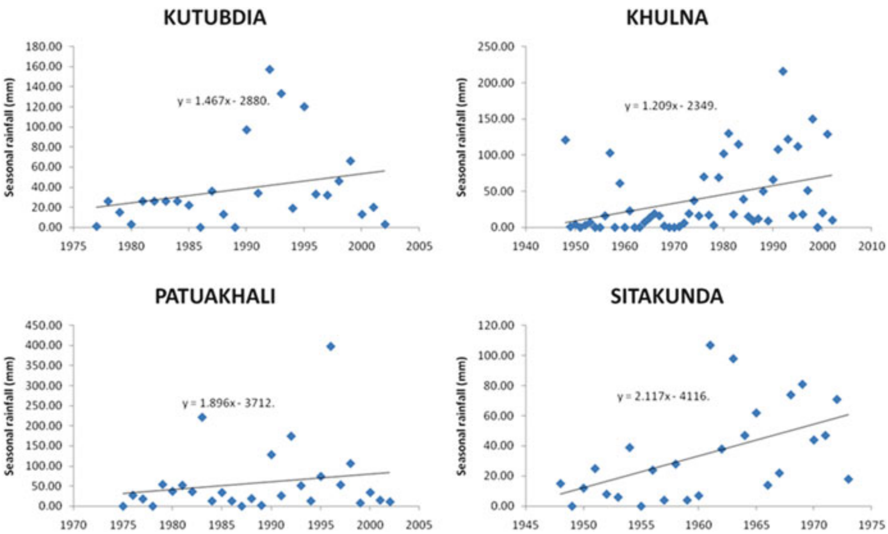


Fig. 2.2 Observed trend in seasonal mean rainfall for winter seasonal month (DJF). *Source*: Author's calculation

where it is found maximum during the pre-monsoon (MAM) and monsoon (JJA) season by around 100 mm increase in the mean seasonal rainfall. Although the winter season (DJF) experiences the minimum rainfall, historical trend is showing a positive inclination in 27 out of 32 rainfall observatories of the BMD. This trend is prominent in the coastal regional stations of Sitakunda, Patuakhali, Kutubdia and in Khulna in the range of 1.2–2.1 mm/year increase in the mean seasonal rainfall. Increase in the Pre-monsoon (MAM) seasonal rainfall is also evident in 30 out of 32 stations of BMD, where it is also prominent in the coastal regional stations of Kutubdia, Mongla, Rangamati and Sandwip stations in the range of 8–13 mm/year increase in the mean seasonal rainfall. Increase in the Monsoon (JJA) rainfall is observed in 18 out of 32 meteorological stations, which is also prominent in the coastal district observatories like in Kutubdia, Mongla, Sitakunda and in Teknaf stations in the range of 21–42 mm/year increase in the mean seasonal rainfall. Post-monsoon (SON) rainfall is also observed to be increase in 24 out of 32 meteorological stations, which is prominent in the coastal observatories of Khepupara, Kutubdia, Mongla and in Teknaf stations in the range of 12–24 mm/year (Figs. 2.2–2.5).

In the recent years, the total number of non-rainy days in a year is also decreasing. A total of 22 out of 32 rainfall stations of BMD are showing a decreasing trend in the total number of non-rainy days in a year. As we have evident before that in the coastal region both the temperature and rainfall is showing an overall increasing trend, in the recent years this region is also experiencing occurrences of more frequent rainfall in a year. This can be evident from the rainfall observations in the Sitakunda, Khepupara, Mongla and in the Hatiya stations (Fig. 2.6).

Ten-day zero rainfall is an index of meteorological drought. As evident from above that most of the regions are experiencing more rainfall in the recent years, the

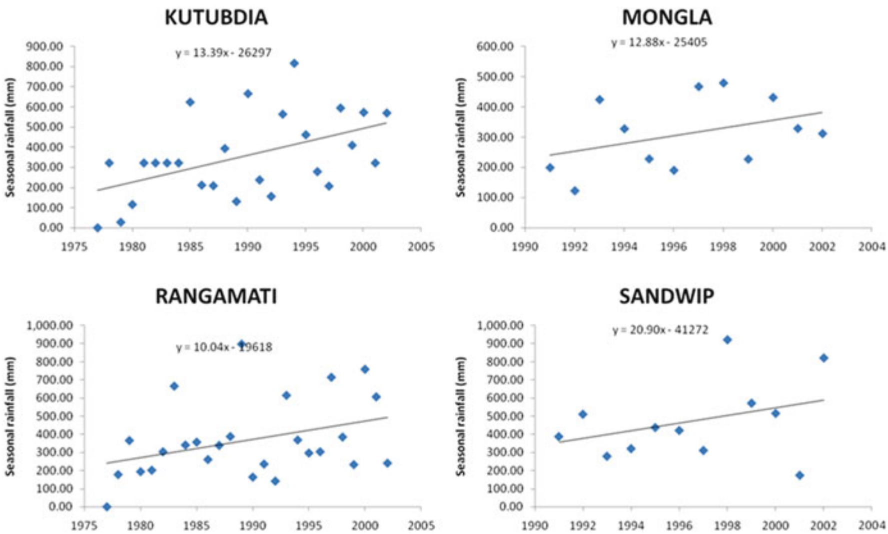


Fig. 2.3 Observed trend in seasonal mean rainfall for pre-monsoon seasonal month (MAM). *Source*: Author's calculation

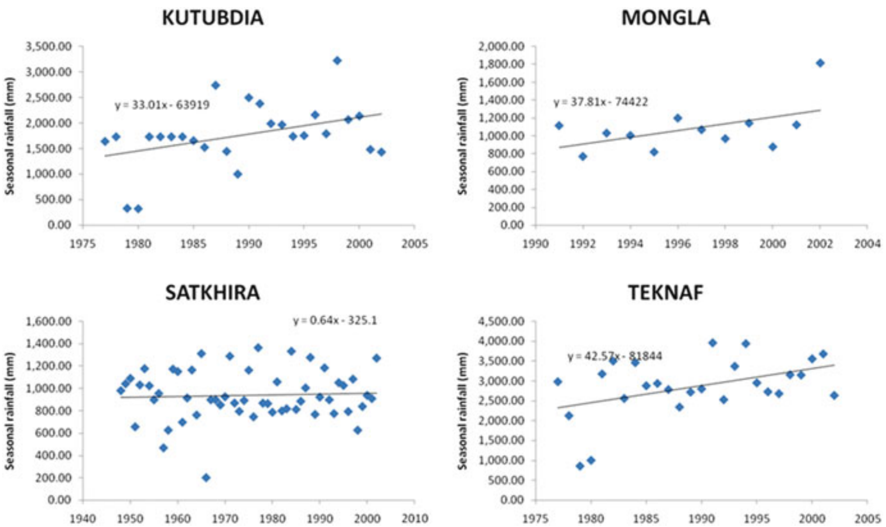


Fig. 2.4 Observed trend in seasonal mean rainfall for monsoon seasonal month (JJA). *Source*: Author's calculation

overall occurrences of meteorological drought is also observed to be decreasing in the recent years. A decreasing trend is observed in a total of 26 out of 32 rainfall stations of BMD. It is also interesting to observe that the stations which are showing a decreasing trend four coastal zone stations can be ranked in the top. The stations are

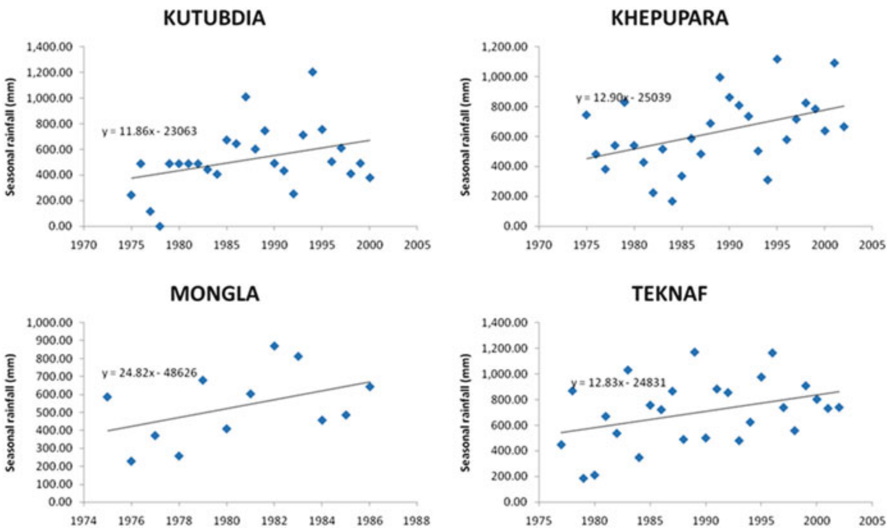


Fig. 2.5 Observed trend in seasonal mean rainfall for post-monsoon seasonal month (SON). *Source*: Author's calculation

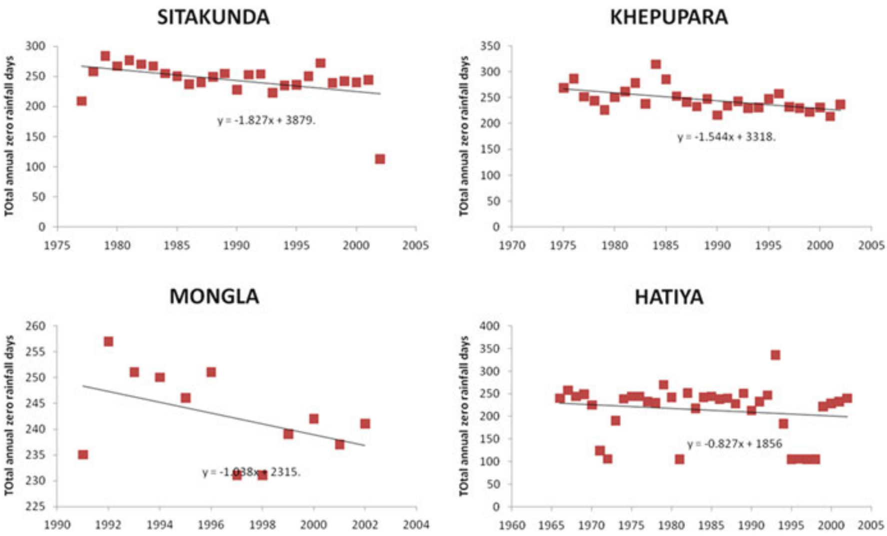


Fig. 2.6 Historical trend in the annual count of zero rainfall days in selected coastal zone rainfall stations of BMD. *Source*: Author's calculation

Khepupara, followed by Bhola, Rangamati and Sitakunda; respective historical trend in terms of total count of 10-day zero rainfall days per year is shown in Fig. 2.7.

In the recent years, the intensity of daily rainfall is also increasing. It is evident from 25 out of 32 rainfall stations of BMD. Out of these stations, coastal rainfall station in Kutubdia ranked highest in terms of the count of number of rainy days/

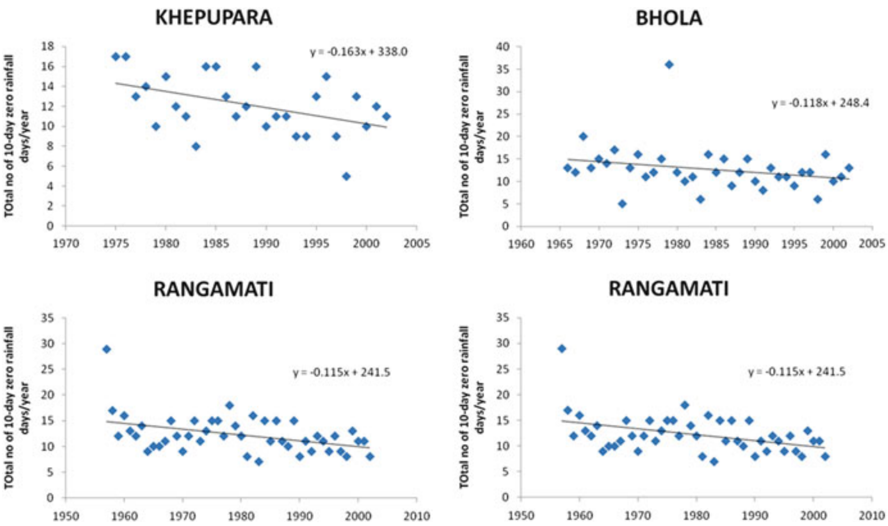


Fig. 2.7 Trend in 10-day zero rainfall in selected stations. *Source*: Author's calculation

year that exceeds the threshold of 95 % non-exceedence probability rainfall value. It is followed by other coastal districts like Mongla, Feni, Khepupara, Teknaf, Sitakunda and Rangamati where the increasing trend is also observed. It is quite alarming to observe one evidence in the Kutubdia, where during the 80s, average annual incidence of exceedence is found as 13 days/year which just increases to double during the next decade (90s).

2.2.3 Climate Change Projections

2.2.3.1 Uncertainties

The Intergovernmental Panel on Climate Change (IPCC) 2007 report highlights uncertainty quantification as one of the most pressing research issues in determining our overall ability to propose how human activities can be modified to mitigate our effects on natural climate and how we can adapt to unavoidable changes (Nychka et al. 2009). Leytham (2010) suggested that it should be recognized that all aspects of climate change impact projections are subject to considerable uncertainty. The scientific research community has concluded with a high degree of confidence that globally averaged air temperatures will increase in the future, however the magnitude of change is quite uncertain and depends on a large number of factors such as future economy activity, technological change, and population growth, which in turn affect the emission of greenhouse gases, and, ultimately, change in air temperature. While increases in air temperature are projected with confidence, there is much lower confidence in projections of change to other meteorological parameters such as precipitation and wind speed. Downscaling coarse resolution GCM model data using statistical of dynamic downscaling techniques by different RCM models are still inadequate or results are not consistent to represent regional or local conditions. Letham (2009) found out that the process involves a long chain of assumptions and simplifications, and a corresponding propagation of, and increase in, uncertainty. Other than this, large scale uncertainty involved with the natural and human activity may not represent the true dimension and extent of climate change impact.

2.2.3.2 Past Reviews

Special Report on Emission SCENARIOS (IPCC 2000)

The Special Report on Emissions Scenarios (SRES) was a report prepared by the Intergovernmental Panel on Climate Change (IPCC) for the Third Assessment Report (TAR) in 2001, on future emission scenarios to be used for driving global circulation models to develop climate change scenarios. The SRES Scenarios were also used for the Fourth Assessment Report (AR4) in 2007, and have been subject to discussion about whether emissions growth since 2000 makes these scenarios obsolete. Scenario families contain individual scenarios with common themes. The four families of scenarios discussed in the IPCC's Third Assessment Report (TAR) and Fourth Assessment Report (AR4) are A1, A2, B1, and B2. Scenario descriptions are based on those in AR4, which are identical to those in TAR (IPCC 2001a, b).

In simple terms, the four storylines combine two sets of divergent tendencies: one set varying between strong economic values and strong environmental values, the other set between increasing globalization and increasing regionalization. Incorporating the effect of climate change for the Padma bridge will mainly follow the A1 storyline and scenario family which assumes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies.

There are subsets to the A1 family based on their technological emphasis:

- A1FI—an emphasis on fossil-fuels
- A1B—a balanced emphasis on all energy sources
- A1T—emphasis on non-fossil energy sources

Third IPCC, Summary for Policymakers, "A Report of Working Group 1 of the Intergovernmental Panel on Climate Change" (IPCC 2001a, b)

The Third Assessment of Working Group I of the Intergovernmental Panel on Climate Change (IPCC) builds upon past assessments and incorporate new results from the past 5 years (1996–2000) of research on climate change. The summary report describes the state of understanding of the climate system and provides estimates of its projected future evolution and their uncertainties. In order to make projections of future climate, models incorporate past, as well as future emissions of greenhouse gases and aerosols. Projections of global average sea level rise from 1990 to 2100, using a range of AOGCMs (atmosphere–ocean General Circulation Model) following the IS92a (Illustrative Scenarios 1992) scenario (including the direct effect of sulphate aerosol emissions), lie in the range 0.11–0.77 m (see Fig. 2.10).

- A thermal expansion of 0.11–0.43 m, accelerating through the twenty-first century;
- A glacier contribution of 0.01–0.23 m;
- A Greenland contribution of −0.02–0.09 m and
- An Antarctic contribution of −0.17 to +0.02 m.

Development and Climate Change in Bangladesh: Focus on Coastal Flooding and the Sundarbans (Agrawala et al. 2003)

OECD (Organization for Economic Co-operation and Development) Development and Climate Change project, an activity being jointly overseen by the Working Party on Global and Structural Policies (WPGSP) of the Environment Directorate, and the Network on Environment and Development Co-operation of the Development Co-operation Directorate. The study projected the climate change and sea level rise for Bangladesh. For precipitation and temperature change projection, 17 GCMs (Global Circulation Model) developed since 1995 were examined for Bangladesh. For the changed frequency and intensity of cyclones, with references of third IPCC report, the study concludes an increase in peak intensity may be in the range of 5–10 %. The study referred to the third IPCC findings on global change for sea level rise.

Formulation of Bangladesh Program of Action for Adaptation to Climate Change Project (WARPO 2005)

As a party to the UNFCCC, the Government of Bangladesh (GoB 2007) has instituted the preparation of the National Adaptation Program of Action (NAPA) for the country. Taking a sectoral approach, a concerted sectoral working group (SWG) concept has been undertaken to develop the Bangladesh NAPA. The important task of developing sectoral NAPA has been assigned to these SWGs that will ultimately be helpful in devising the BDNAPA. Water Resources Planning Organization (WARPO) was assigned to coordinate the BDNAPA activities for four sub-sectors namely: Water, Coastal Areas, Natural Disaster and Health. The National Adaptation Programme for Action (NAPA) for Bangladesh (NAPA 2005) adopted the results obtained by Agrawala et al. (2003) for changes in temperature, but slightly modified them for precipitation.

Fourth IPCC, Technical Summary, "A Report of Working Group 1 of the Intergovernmental Panel on Climate Change" (IPCC 2007a)

Climate Change 2007, the Fourth Assessment Report (AR4) of the United Nations Intergovernmental Panel on Climate Change (IPCC), is the fourth in a series of reports intended to assess scientific, technical and socio-economic information concerning climate change, its potential effects, and options for adaptation and mitigation. The report is the most exhaustive and presents detailed summary of the climate change situation ever undertaken, involving thousands of authors from dozens of countries, and states in its summary the following.

- Warming of the climate system is unequivocal.
- Most of the observed increase in global average temperatures since the mid-twentieth century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.

In the 6 years since the IPCC's Third Assessment Report (TAR), significant progress has been made in understanding past and recent climate change and in projecting future changes. These advances have arisen from large amounts of new data, more sophisticated analyses of data, improvements in the understanding and simulation of physical processes in climate models and more extensive exploration of uncertainty ranges in model results.

The concentration of atmospheric CO_2 has increased from a pre-industrial value of about 280–379 ppm in 2005. The CH_4 abundance in 2005 of about 1,774 ppb is more than double of its pre-industrial value. The N_2O concentration in 2005 was 319 ppb, about 18 % higher than its pre-industrial value. Over the 1961–2003 period, the average rate of global mean sea level rise is estimated from tide gauge data to be 1.8 ± 0.5 mm/year.

Sea level rise (in the Bay of Bengal) reflects the combined effects of global sea level rise, local changes in sea level due to ocean density and circulation changes relative to the global average and may also be influenced by local vertical land movement (e.g. subsidence or uplift) in the vicinity of the bridge site.

Previous estimates and uncertainties for sea level rise, the scenarios have so far been largely speculative, not based on any detailed modeling. UNEP (1989) showed 1.5 m sea level rise in Bangladesh coast by 2030, affecting 22,000 km^2 (16 % of total landmass) area with a population of 17 million (15 % of total population) affected. Since this scenario was calculated in 1989, the expected rate of sea level rise has been modified because of uncertainty. The BUP-CEARS-CRU study (1994) did not draw detailed estimates in relation to change in sea level; however it commented that both sedimentation and subsidence were likely to complicate net changes in sea level along the Bangladesh coast. Speculative scenarios of 30 and 100 cm sea level rise as lower and upper bound limits have been considered in a number of studies (BCAS-RA-Approtech 1994; Ali 1999). WB (2000) showed that 10 cm, 25 cm and 1 m rise in sea level by 2020, 2050 and 2100; affecting 2 %, 4 % and 17.5 % of total land mass respectively. Milliman et al. (1989; cited in Frihy 2003) reported 1.0 cm/year sea level rise in Bangladesh. In the absence of any

Bangladesh-specific sea level rise scenario, the IPCC scenarios for sea level rise have generally been used as a basis for developing net sea level change along the coastal zone of Bangladesh, as cited in WARPO (2001). MoEF (2002) considered a linear rise in sea level by 1 cm/year, which resulted in 30 and 50 cm rise in sea level by the year 2030 and 2050, respectively. The latter scenarios were forwarded by the Government of Bangladesh in its First (Initial) National Communication. The OECD study (Agrawala et al. 2003) did not specify any sea level rise scenario for its analysis. However, it reiterated the fact that both subsidence and sedimentation would complicate the outcome. Moreover, it stressed considering mean sea level rise in conjunction with cyclonic activities and subsequent tidal surges. The NAPA document provided a sea-level rise scenario for Bangladesh, but without explanation. Apparently, the upper values of the IPCC SLR Scenario (IPCC 2001a, b) was adopted for developing the scenarios for 2050 and 2100, while the curve was extrapolated for developing the 2030 scenario.

2.3 Risks and Vulnerability

2.3.1 Impact of Climate Change on Water Resources System

2.3.1.1 Climate Change and Hydrological Events

Technical paper on climate change and water publishes by IPCC (Bates et al. 2008) stated that observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems. The hydrological system is sensitive to changes in climate (Arnell et al. 1996). The interaction between increases in greenhouse gases and the hydrological system are very complex and shown in Fig. 2.8.

In a nutshell the interaction between the physical process of climate change and its impact in the hydrologic regime can be viewed as follows:

- Increased in temperature will result in changes in evapo-transpiration, soil moisture, and infiltration.
- Increased atmospheric CO_2 may increase global mean precipitation.
- Increased temperature will result in the rise in the global sea level caused by the thermal expansion of ocean water due to warming and increase in the ocean mass (principally from land-based sources of ice like glaciers and ice caps, and the ice sheets of Greenland and Antarctica).
- Changes in the precipitation event could affect water availability in soils, rivers and lakes with negative implication in the demand-supply equilibrium.
- Increased evapo-transpiration enhances the water vapor content if the atmosphere and the greenhouse effect, and the global mean temperature may rise even higher.

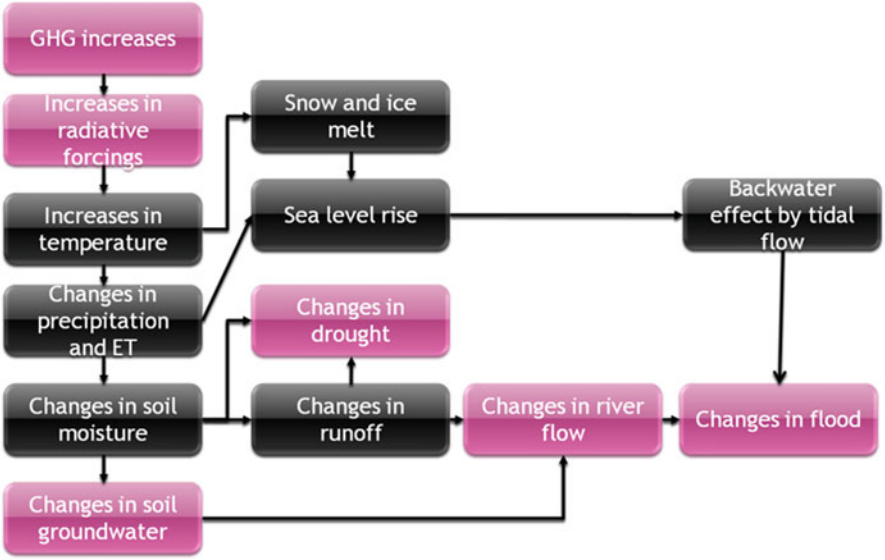


Fig. 2.8 Climate change and impact on water resources (Mirza and Ahmad 2005)

2.3.1.2 Water Resource Supply Demand

Hydro-meteorological disasters are the principle climate induced hazards that make the water resources system vulnerable. A brief list of climate induced hydro-meteorological hazards is listed below:

– Extreme variability of rainfall evolves the risks of water-related climate variability, which are likely to intensify and worsen.
– **Bangladesh is highly vulnerable to droughts and floods**. Climate change is going to affect the intensity, duration and timing of occurrences of these events.
– **Sea level rise is anticipated to inundate the southern region of Bangladesh permanently** which will make millions of peoples to migrate in the upstream, will destroy the agrarian economy in the coastal region.
– **Cyclone and storm surge in the Bay of Bengal is anticipated to be increased** in terms of frequency and intensity. Projected rise in the sea level will further aggravate the situation.
– **Water scarcity is another challenge**. Already, all over the major rivers, water availability has started declining and this trend is projected to continue in future. Other than this, availability of freshwater in the coastal region due to salinity ingress is anticipated to decrease water stress or per capita water availability. Groundwater aquifers will be contaminated which is going to aggravate the situation further.
– **Erratic behavior in the meteorological events will cause health hazard** all over Bangladesh. Water and vector borne diseases are anticipated to spread like epidemic with more geographical coverage and affecting more population.

Each of the above mentioned hydro-meteorological variability due to climate change impact is discussed in the following sections.

2.3.1.3 Flooding and Drainage

Four main types of natural floods occur in Bangladesh: flash floods, river floods, rainwater floods, and coastal floods induced by storm surges (Ahmed et al. 1994; Ahmed and Mirza 2000). A total of 28 major river floods occurred in the past five decades. Flat topography, heavy rainfall, geographical location, trans-boundary flows and the act of the global warming including socio-economic and flood conditions add complications to Bangladesh's flood problem. A 53-year (1954–2007) data shows that all four most extensive floods occurred after 1986 (1987, 1988, 1998, 2004) and it is striking that two record floods (1988 and 1998) have a return period of 100 years or more. At the same time, since 1975, low flood extents have become more frequent. Lowest flood-affected areas over the 50-year period all occurred after 1980 (1982, 1990, 1992, 1994 and 2001). In addition, if we plot the whole time series in terms of percentage of inundation coverage, we find that the extent of big floods seems to have gradually decreased (see flood-affected areas 1955, 1974, 1987, 1988 and 1998). But if we consider the occurrence of big floods (more than 25 % of inundation coverage) over the stipulated period, we find that the frequency of big floods is increasing in the recent years.

The riverine flood (or monsoon flood) is affected by the following climate change related phenomenon:

- Change in the frequency and intensity in extreme rainfall event may subsequently increase the intensity of flood.
- Rise in the sea level may cause the backwater effect causing the rise in the river water level, or obstacle the upstream discharge to be drained off into the sea.
- Increase in the soil moisture may increase the physical runoff or overland flow.
- Possible changes in temperature, precipitation and evapo-transpiration may result in the change in soil moisture, groundwater recharge and runoff and could intensify flooding and droughts in various climatic zones.

Flooding is largely dependent upon extreme rainfall events. A number of literatures addressed the physical process of climate change and its consecutive impact on flood regimes (Gordon et al. 1992; Whetton et al. 1993; Kattenberg et al. 1996; Arnell et al. 1996; McGuffie et al. 1999; Roeckner et al. 1999; Lal et al. 2000; Hu et al. 2000; IPCC 2001a, b, 2007a, b). IPCC (2001a) concluded that relatively small climatic changes can cause large water resources problem, particularly flood vulnerable areas of India and Bangladesh. Gordon et al. (1992) and Whetton et al. (1993) indicate that global warming may produce changes in the frequency of intense rainfall because of possible changes in the paths and intensity of depressions and storms; and possible increase in convective activity. Lal et al. (2000) found that there is also an increase in intra-seasonal precipitation variability and that both intra-seasonal and inter-annual increase is associated with intra-seasonal connectivity during the summer. On the contrary, Asian summer monsoon precipitation may be decreased as a result of the dampening effect caused by Sulphate aerosols (Kattenberg et al. 1996; Roeckner et al. 1999). But climate model experiments suggest that rainfall intensity and number of wet spells are likely to increase in greenhouse gas concentrations (McGuffie et al. 1999; IPCC 2001a, 2007a, b). Despite the research debate, evidence from climate models and hydrological studies suggest that flood frequencies are likely to increase with global warming, though the amount of increase is very uncertain and for a given change in climate, will vary considerably between catchments (Arnell et al. 1996) and at finer resolutions (Kattenberg et al. 1996; IPCC 2007a, b).

In Bangladesh, a number of hydrological models (empirical and water balance modeling carried out by Mirza and Ahmad 2005; Tanner et al. 2007; Farquharson et al. 2007; CCC 2009) have been used to assess the impact of climate change on the riverine flooding of Bangladesh. Mirza et al., (2001) identified that future changes in the precipitation regime have four distinct implications:

- Change in the timing of flood due to possible changes in the seasonality;
- Increase in the magnitude, frequency, depth, extent and duration of floods;
- Change in the timing of peaking and change in the likelihood of synchronization of flood peaks of the major rivers; and
- Dramatic change in the land-use patterns in Bangladesh.

Mirza et al., (2001) also showed that a 20-year return period flood event in the Ganges, Brahmaputra and Meghna River will be changed to 13-, 15- and 5.5-year return period floods due to a possible increase in temperature by 2 °C; which means the catastrophic flood[1] events. For extreme level rise in temperature by 6 °C, return period of the same frequency catastrophic flood event will reduce by 3.4 times, 2.3 times and 8.5 times for the Ganges, Brahmaputra and Meghna rivers respectively.

2.3.1.4 River Bank Erosion

Riverbank erosion is one of the major natural disasters of Bangladesh. It has caused untold miseries to thousands of people every year living along the banks of rivers in Bangladesh. To date, erosion alone has rendered millions of people homeless and has become a major social hazard. People, who live adjacent to riverbank, become victim of erosion and be forced to change their livelihood and community. Most of the victims of riverbank erosion become slum dwellers in large urban and metropolitan. Major rivers like the Jamuna, the Ganges and the Padma eroded around 1,590 km^2 floodplains making 1.6 million people homeless since 1973. Furthermore these rivers have inside apparently permanent char lands. Not only the floodplain the char land dwellers are always vulnerable to river erosion. River-wise status of riverbank erosion of these major rivers is being given in the following sub-sections.

[1]Range of flooded area 50,000–57,000 km^2 and range of % inundation 34–38.5 %, as classified by Mirza et al. (2001).

Table 2.1 Bank erosion along the Jamuna River during the period 1973–2009

District	Eroded area (ha)	Accreted area (ha)
Kurigram	18,510	40
Gaibandha	9,220	920
Jamalpur	11,810	4,880
Bogra	10,500	1,880
Sirajganj	22,400	2,410
Tangail	10,920	
Pabna	1,770	
Manikganj	5,700	10
Total	**90,830**	**10,140**

Source: CEGIS (2010)

It has been found that for the last few decades shows that the river is widening and both banks are migrating outwards at a high rate. During the last three and half decades (1973–2009), the net erosion along the 240 km long Jamuna River was about 80,690 ha (BWDB 2009). The rate of erosion has varied over time. For example, the rate at which the Jamuna River has been widening declined from 150 m/year in the 1970s and 1980s to 48 m/year during the last 14 years. The total erosion and accretion in the districts along the Jamuna River since 1973 is presented in Table 2.1.

Between 1973 and 2009, erosion and accretion along the Jamuna River was 90,830 and 10,140 ha respectively. This imbalance between erosion and accretion is attributed to the widening of the river (Fig. 2.9). The highest erosion was in Sirajganj district (22,400 ha) and the lowest in Pabna district (1,770 ha).

For the last few decades show that the Ganges is almost stable in width, even though the river is shifting continuously. This indicates equilibrium of erosion and accretion. During the last three and half decades (1973–2009) the net erosion along the 230 km long Ganges in the territory of Bangladesh was about 2,710 ha (BWDB 2009). The total erosion and accretion in the districts along the Ganges River since 1973 are presented in Table 2.2. Between 1973 and 2009, erosion along the Ganges River was 28,390 ha while accretion was 25,680 ha. The balance between erosion and accretion along the Ganges River shows the stability of the river in width (Fig. 2.10). The most affected district by the Ganges River erosion was Kushtia (12,180 ha).

2.3.1.5 Impacts on Water Resources

Availability of fresh water in Bangladesh is highly seasonal. Based on rainfall patterns, four seasons can be distinguished. About 75 % of the annual rainfall occurs during the monsoon (June–September). Annual rainfall ranges from 1,400 mm in the western Rajshahi region to over 5,000 mm in the northeastern Sylhet region (World Bank 2000). In the post-monsoon (October–November) and winter period

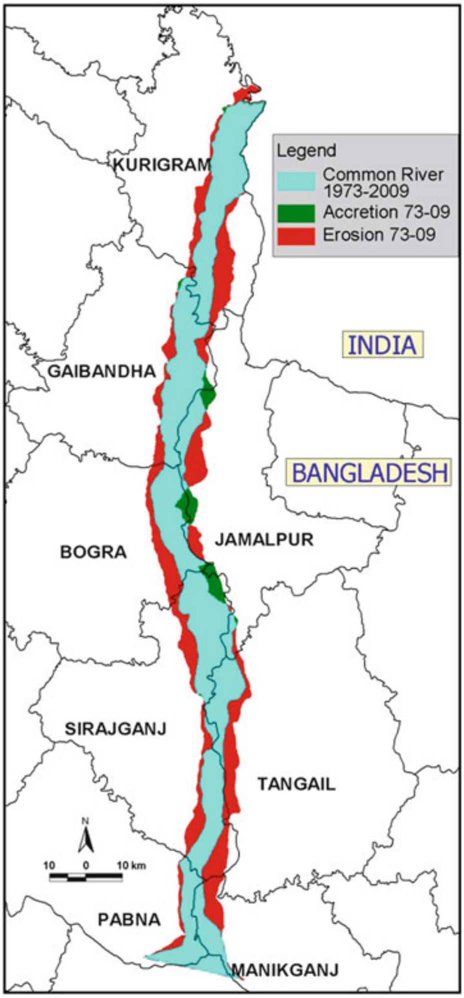


Fig. 2.9 Erosion–accretion along the Jamuna during 1973–2009. *Source*: CEGIS (2010)

Table 2.2 Bank erosion along the Ganges River during the period 1973–2009

District	Eroded area (ha)	Accreted area (ha)
Nawabganj	5,160	11,990
Rajshahi	1,220	1,340
Natore	1,920	140
Kushtia	12,180	1,220
Pabna	2,440	8,290
Rajbari	5,470	2,700
Total	**28,390**	**25,680**

Source: CEGIS (2010)

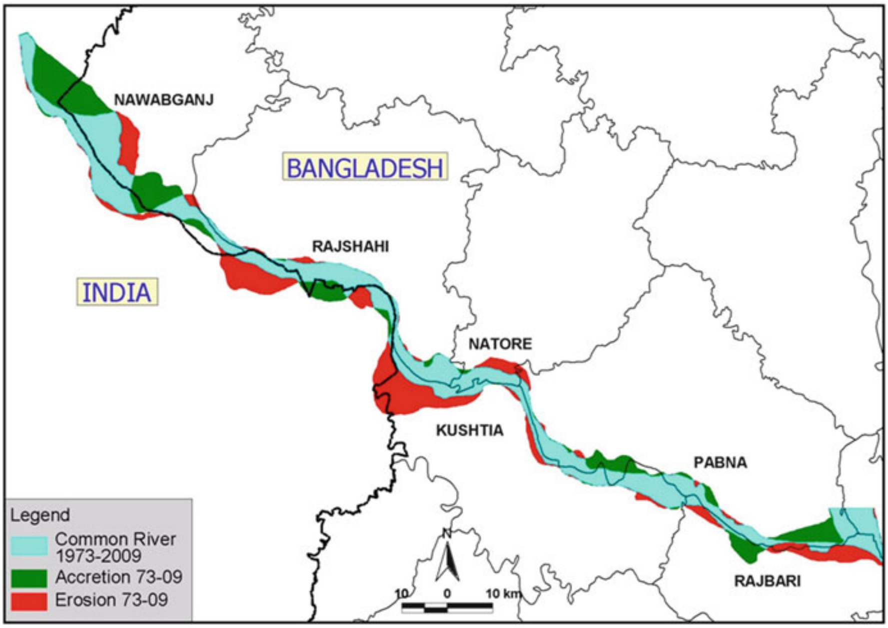


Fig. 2.10 Erosion–accretion along the Ganges during 1973–2009. *Source*: CEGIS (2010)

(December–February) only 10 % of the annual rainfall is available, making agriculture highly dependent on remaining soil moisture and irrigation from surface and groundwater. In the subsequent pre-monsoon period (March–May), on an average, there is 15 % of the annual amount of rainfall. Rainfall is extremely unreliable in this period.

Seasonality is reflected in river discharges as well. Figure 2.11 presents comparisons of average July-rainfall in major river basins with respect to total rainfall in 1998. WARPO (2001) estimated that around 90 % of the mean dry season stream flow is found in the Ganges, the Brahmaputra and the Meghna rivers. Smaller regional rivers carry the remaining 10 %. In terms of water availability, March is a critical month in Bangladesh. The Brahmaputra accounts for 58 % of the flow measured within the country, whereas the share of the Ganges is only 13 %. The Meghna discharge contributes only 2 % of the total measured discharge in Bangladesh during the month of March. It is estimated that the ratio between the discharges of the dry and monsoon seasons for the Ganges River is 1:6 (Mirza and Dixit 1997).

With respect to water supply, it is *very likely* that the costs of climate change will outweigh the benefits globally. One reason is that precipitation variability is *very likely* to increase, and more frequent floods and droughts are anticipated. The risk of droughts in arid basins in the low-flow season will increase. The impacts of floods and droughts could be tempered by appropriate infrastructure investments and by changes in water and land-use management, but the implementation of such measures will entail costs (US Global Change Research Program 2000). Water infrastructure, usage patterns and institutions have developed in the context of current

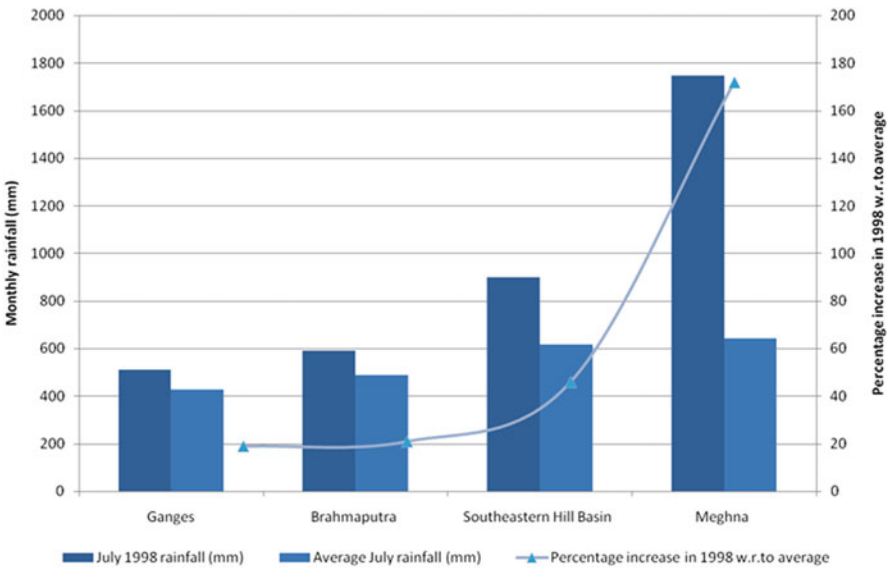


Fig. 2.11 Comparison of peak monsoon monthly rainfall between a mega flood and monthly average

conditions. Any substantial change in the frequency of floods and droughts, or in the quantity and quality or seasonal timing of water availability, will require adjustments that may be costly, not only in monetary terms but also in terms of societal and ecological impacts, including the need to manage potential conflicts between different interest groups (Miller et al. 1997).

Hydrological changes may have impacts that are positive in some aspects and negative in others. Increased runoff could also damage areas with a shallow water table. In such areas, a water-table rise disturbs agricultural use and damages buildings in urban areas. In addition, an increase in annual runoff may not lead to a beneficial increase in readily available water resources, if that additional runoff is concentrated during the high-flow season. Apart from this, increased precipitation intensity may result in periods of increased turbidity and nutrient and pathogen loadings to surface water sources.

In Bangladesh, the largest demand for both surface and groundwater is to support irrigation in the dry months. However, in setting priorities for allocating water during critical periods, the National Water Policy gives this sector a relatively low priority and sets the following order: domestic and municipal uses, non-consumptive uses (e.g., navigation, fisheries and wild life), sustenance of the river regime, and other consumptive and non-consumptive uses including irrigation, industry, environment, salinity management, and recreation (WARPO 1999).

By 2018, demand for irrigation may reach 58.6 % of the total supply. Demand for other sectors is estimated to reach 40.7 % for navigation, salinity, and fisheries, and 0.7 % for domestic and industrial uses (WARPO 2001). It should be noted that these estimates do not take into account the effects of possible changes in climate. The following paragraphs discuss the possible influence of climate change in the estimation of the water requirements for the various sectors.

Changes in climate may affect irrigation requirements for all the three cropping seasons: Rabi, Kharif-I, and Kharif-II. Increase in temperature will lead to escalating irrigation demands by 200 M m^3 for March only (Brammer et al. 1996). With sea level rise, the saline-water front will move farther inland. Migratory fresh water fish hatchlings cannot survive even in moderately saline (2,000 mmhos/cm) water (EGIS-II fisheries expert). With declining number of hatchlings in the dry season, one may expect that the overall fish production in the floodplains will decline significantly.

Due to siltation, many regional rivers such as the Gorai River have lost their connection with their perennial water source in the dry season (Mirza 1997). Therefore, lower river flows, rising bed levels, and increased morphological dynamics will likely deteriorate further the flow conditions of the smaller channels as well as their navigability in winter. Climate change induced low flow and high evaporation will reduce availability of surface water in the water bodies including rivers, artesian wells and ponds—and thereby accentuate the prevailing crisis of drinking water in the dry season. Scarcity may arise because of mining of groundwater caused by over-pumping changes in water supply and demand caused by climate change will be overlaid on top of changing water use due to growths in both population and income. Currently Bangladesh withdraws 22,500 million m^3 of water (WRI 1998). According to the WARPO (2001), the total requirement for water consumption in 2020 will be 24,370 million m^3, and supply will be 23,490 million m^3. Thus, there would be a shortage of 880 million m^3. Agriculture is estimated to constitute 58.6 % of demand; navigation, salinity and fisheries 40.7 %, and municipal and industrial demand will be only 0.7 %. It is also estimated that on a yearly basis, about 77 % of water supply comes from surface water sources.

Although monsoon availability of water will increase under climate change, it is highly likely that the winter water availability will decrease, and more water will be required for irrigation in winter. Keeping the projected shortfall in mind, one may infer that irrigation will be more dependent on groundwater withdrawal. While the ground water is fully replenished every year, the availability of (shallow) groundwater in the dry season is finite. Under such a condition, it would be quite difficult to control salinity intrusion, to keep navigational routes functional, and to ensure environmental and ecological harmony in various places—especially in the Ganges, Atrai and Teesta dependent areas of the country.

Climate change affects groundwater recharge rates (i.e., the renewable groundwater resources) and depths of groundwater tables. However, knowledge of current recharge and levels in both developed and developing countries is poor; and there has been very little research on the future impact of climate change on groundwater, or groundwater–surface water interactions. In Bangladesh, a recent study carried out by the World Bank (2010) indicates that the groundwater resources in the coastal zone of Bangladesh are highly vulnerable in the following aspects:

- Deep fresh coastal groundwater is vulnerable to vertical infiltration of saltwater due to periodic storm surge flooding.
- There is moderate vulnerability of the fresh coastal groundwater resource to lateral saltwater migration.
- There is high vulnerability to salinization due to pumping-induced mixing of preexisting fresh and saline groundwater.
- Groundwater in areas with lower topographic relief (central delta) is far more vulnerable to vertical and lateral intrusion pathways.

Other than this, as many ground waters both change into and are recharged from surface water, impacts of surface water flow regimes are expected to affect groundwater. Increased precipitation variability may decrease groundwater recharge in humid areas because more frequent heavy precipitation events may result in the infiltration capacity of the soil being exceeded more often. Specially, groundwater is the key source of potable water in the coastal region. If this resource becomes unfit for drinking purpose then around one third of the total population of Bangladesh will have no alternative in the search for fresh drinking water.

2.3.1.6 Impacts on Agriculture

Agriculture is a major sector of Bangladeshi economy, providing about 22 % of total GNP. Perhaps more important is the fact that almost two-thirds (65 %) of the labor force is employed in agriculture (Faruquee 1998). Rice is by far the major crop in Bangladesh. In 1992–1995, average annual production was 18 Mmt. In contrast, only 1.2 Mmt of wheat was produced annually in the same period (BBS 1998). But IPCC-IV has stated that Results of recent studies suggest that substantial decreases in cereal production potential in Asia could be likely by the end of this century as a consequence of climate change. However, regional differences in the response of wheat, maize and rice yields to projected climate change could likely be significant (Parry et al. 1999; Rosenzweig et al. 2001).

Farmers in Bangladesh are quite poor, even in comparison with its neighboring countries. The average size of farms is very small. A recent estimate shows that over 70 % of farm families have less than 1.0 ha (2.5 acres) and 80.3 % has less than 2 ha (5.0 acres) land. The farms are undercapitalized, and lack the usual inputs of quality seed, fertilizer, pest control etc. (Ahmad and Hasanuzzaman 1998). In addition, Bangladeshi farmers have little mechanized agricultural tools. For example, in the early 1990s, there were 5,300 tractors in Bangladesh, whereas Pakistan with about twice the area for agriculture had more than 54 times the number of tractors (WRI 1998).

Published sources on the effect of climate change on rice yields tend to show minor negative to positive effects at low temperature changes associated with slight CO_2 fertilization effect. For example, Karim et al. (1996) estimated that an increase of 2 °C with unconstrained water supplies (no moisture stress) would increase rice yields only slightly. A temperature increase of 4 °C (higher than projections for 2050) will results in mixed yield changes. Rice yields for 2020 and 2050 were calculated based on the results of Karim et al. (1996) and assuming no moisture stress, and relatively strong CO_2 fertilization effect. The results show a small positive change in yields. Wheat yields are projected to decrease at both temperature changes, even with optimistic assumptions on the CO_2 fertilization effect.

Previous agricultural yield estimates were based on information published on the positive effects of higher atmospheric carbon dioxide levels on plant growth at the time the studies were carried out. Recent analyses have shown that increased CO_2 levels essentially help to attain higher leafarea index, and do not contribute to increased rice yields (Abrol 1998). These results have supplemented the findings of Walker and Steffen (1997). It may be too early to come to a conclusion regarding the direct effects of climate change on food-grain production. There are, however, indirect effects in relation to induced changes in floods and salinity.

At present, western parts of Bangladesh are periodically being affected by droughts in winter months. Since the temperature will rise, and there exists a strong possibility that the winter precipitation will decrease further, it is likely that the moisture content of topsoil would decrease substantially leading to severe moisture stress. Higher temperature would, furthermore, induce higher rates of evapotranspiration leading to acute (phenological) drought conditions in winter months. Consequently, a late Kharif II drought in December would adversely affect Aman crop at the ripening stage, while an early Rabi drought would more severely affect wheat and Boro crops at both germination and vegetative growth stages (Karim et al. 1998). Furthermore, increasing moisture stress in early Kharif I would affect Aus production significantly. Increased drought will increase capillary action and salinity build up in the top soil as well. Detailed processes of salinity build up are explained in Karim et al. (1990). On an average year, increased salinity not only causes a net reduction of about 0.2 Mmt of rice production, but also diminishes potentials of Boro and wheat cultivation in saline affected soils of the coastal areas. With the possibility of increasing soil salinity under climate change scenarios, it is highly likely that food-grain production in those areas would be extremely vulnerable. It is reported that, the effect of soil salinity on Aus production would be detrimental, and Aman, when grown under a severe climate change scenario, could also suffer over twofold yield reductions (Habibullah et al. 1998). Recently, CEGIS (2006) has shown sea level rise along the southwestern region of Bangladesh Aman suitability decrease significantly.

Together with the possible reduction in Aman rice area (as a result of greater spread of flood waters, and longer duration of flooding) and a reduction in the Boro rice area (which will be limited by available surface and groundwater for irrigation), the total area suitable for rice production may in the future stagnate or possibly decrease.

Another influence on the total available area for agriculture is that: climate change is expected to disturb the sediment balance. It is difficult to forecast whether there will be net accretion or erosion. However, it is important to remember that newly accreted land along the coast may take up to 15 years to develop full production potential, whereas land lost to erosion is in most cases valuable agricultural land. Despite this fact, average accretion in Bangladesh is close to one thousand hectares per year of valuable agricultural land. At present this land is "state-owned". A coherent land use policy with appropriate support services (for example, access to information) for this state-owned land is urgently needed to avoid (the often illegal) settlements before the soils have developed their full productive capacity.

Floods affect agricultural production significantly. The 1988 flood caused reduction of agricultural production by 45 % (Karim et al. 1996). Similarly, Aman production potential of some 2–2.3 Mha could not be realized due to the devastating floods in 1998 that lasted for about 67 days. Since seedlings could not be planted in the flood affected areas, the resulting estimated shortfall of food grain production exceeded 3.5 Mmt. Higher discharge and low drainage capacity, in combination with increased backwater effects would increase frequency of such devastating floods under climate change scenarios. Prolonged floods would tend to delay Aman plantation, resulting in significant loss of potential Aman production, as observed during the floods of 1998.

Considering all the direct and induced adverse effects of climate change on agriculture, one may conclude that crop agriculture would be even more vulnerable in Bangladesh under a warmer world.

2.3.1.7 Impacts on Infrastructures

Floods, especially the high intensity floods, often devastate physical infrastructure such as road networks, educational centres, market places, administrative buildings etc. (Nizamuddin et al. 2001; Siddiqi 1997; Siddique and Chowdhury 2000). Among this, a large road and highway network is criss-crossing the whole Bangladesh like veins, most of it traversing through the flood plains of the country. The Roads and Highways Department (RHD) is responsible for a huge number of assets in the form of roads, bridges and culverts. Protecting and maintaining about 20,798 km of roads and 14,712 bridges and culverts with an estimated asset value of TK 727,000 million is of prime importance for the national economy.

Deluge of 1998 rendered most parts of Dhaka inaccessible by motorized vehicles, while the floodwater of 1988 penetrated the runways of Dhaka International Airport and disconnected it for about 11 days from the rest of the world. The telecommunication network was torn off during the cyclone of 1991 and the entire coastal belt was disconnected for weeks.

Historical records show that the roads, which were raised above the 1988/1998 flood-level, suffered minimum damage in the 2004 floods. After the 1988 flood, for example, national highways such as the Dhaka–Chittagong, Dhaka–Mawa–Khulna, Dhaka–Sylhet and Dhaka–Aricha highways were raised by 1–1.5 m above HFL. As a result, these highways suffered no significant damages during the 2004 flood. Flood loss potentials to roads infrastructure have been huge. In the 1998 and 2004 flood, for example, the direct damage to roads sector is estimated as TK 15,272 and

TK 10,031 million, accounting for 15 % and 9 % of the total damage respectively. The situation is expected to be deteriorating in the days to come, with the increased extent and intensity of flooding due to potential climate change and sea level rise in future. Hence, it is important to develop flood proofing systems as a response to natural disasters, in designated flood risk zones, to protect life, property and vital infrastructure such as roads.

Climate change induced high intensity events pose huge threats to existing physical infrastructure. Damage to national highways due to flood alone is estimated at 1,011 and 3,315 km by the year 2030 and 2050, respectively. The corresponding damage to embankments is estimated at 4,271 and 13,996 km by the year 2030 and 2050, respectively. The aggregated damage figures for health centres and hospitals due to floods, cyclones, sea-level rise and salinity intrusion is estimated at 1,682 and 5,212, respectively, for the above two time horizons (BRTC-BUET 2005).

In this regard, removal of impediments of drainage (dredging/re-excavation of choked rivers/khals; drainage canals), construction of drainage structures (culverts, bridges, and regulators), rehabilitation of structures such as roads, embankments etc. should be considered as adaptation measures towards facilitating drainage and reduce flood-related vulnerability (Ahmed et al. 1998; Ahmed 2005; Faruque and Ali 2005). In view of urban flooding, this option will remain as an important adaptation option despite the high cost of its implementation. In increasingly flood vulnerable areas (FVA), efforts should be made for flood proofing of infrastructure, as deemed necessary (Faruque and Ali 2005).

DFID-sponsored programme "Roads and Highways Policy Management, budgetary and TA Support" (RHD) considered flood as direct disaster and adaptation cost was enumerated considering the flood-proofing of roads and highways by raising this infrastructure above the highest ever-recorded flood levels within the. Specifically, some 170 km of national and regional roads and some 518 km of district (feeder) roads in high risk areas will be raised by 1 m. Further, about 124 km of national and regional roads in low risk area will be raised by 0.5 m. As the option comprises a long-term programme and since the costs would be very high if incurred at one time, it proposes action when a particular road is due for major maintenance or re-surfacing, with priority given to high risk areas.

Flood-proofing of roads and highways should be done by raising road height to the highest recorded flood and provision of adequate cross-drainage facilities. The Roads Master Plan (Government of Bangladesh 2007) also recently reiterated the maintenance of 1–1.2 m freeboard above a 50 year flood, although directives in this respect have been in existence since the time of the floods back in 1987 and 1988. Notwithstanding the above facts, so far, the efforts and resources of the RHD are meager compared to the enormous dimension of the problem. The proposed option in its entire scope will provide appropriate flood proofing to nearly 800 km of roads through roads raising across the country.

In recent time, relevant experts suggested that roads constructed along the east–west direction were given extra attention to ensure proper drainage of water, by providing extra spans for adequate passage at the peak flow stage. Experts also warned that the existing bituminous pavements are more susceptible to water than cement-concrete ones. Provision of asphalt concrete topping and hard shoulder can reduce the damage to roads caused by the flow of water over the road surface. Asphalt concrete produce more durable pavements than the usual road with mixed carpeting. Knowledgeable people also opine that in order to minimize the erosion of the road embankments and vulnerable road sections, slopes have to be protected with hard layers (C.C. blocks with geotextile); less vulnerable sections should be protected with flood resistant natural turfs and plants like vetiver (Kashful).

References

Abrol IP (1998) Sustaining rice-wheat cropping system productivity in the Indo-Gangetic Plains. In: Horiuchi H, Tsubota K (eds) The 4th JIRCAS international symposium: sustainable agricultural development, compatible with environmental conservation in Asia, pp 155–165

Agrawala S, Ota T, Ahmed A, Smith J, Aalst Mv (2003) Development and climate change in Bangladesh: focus on coastal flooding and the Sunderbans. Organisation for Economic Co-operation and Development (OECD), Paris

Ahmad QK, Hasanuzzaman SM (1998) Agricultural growth and environment. In: Faruqee R (ed) Bangladesh agriculture in the 21st century. University Press Ltd, Dhaka, pp 81–108

Ahmed AU (2005) Adaptation options for managing water-related extreme events under climate change regime: Bangladesh perspectives. In: Mirza MMQ, Ahmad QK (eds) Climate change and water resources in South Asia. A. A. Balkema Publishers, Leiden

Ahmed AU, Mirza MMQ (2000) Review of causes and dimensions of floods with particular reference to flood '98: national perspectives. In: Ahmed QK, Chowdhury AKA, Imam SH, Sarker M (eds) Perspectives on flood 1998. University Press Limited, Dhaka, pp 67–84

Ahmed QK, Warrick RA, Ericksen NJ, Mirza MQ (1994) The implications of climate change for Bangladesh: a synthesis. In: Warrick RA, Ahmad QK (eds) The implications of climate and sea-level change for Bangladesh. Bangladesh Unnayan Parishad, Briefing Document No. 7, Dhaka. Kluwer Academic, Dordrecht

Ahmed AU, Alam M, Rahman AA (1998) Adaptation to climate change in Bangladesh: future outlook. In: Huq S, Karim Z, Asaduzzaman M, Mahtab F (eds) Vulnerability and adaptation to climate change for Bangladesh. Kluwer, Dordrecht, pp 125–143

Ali A (1999) Climate change impacts and adaptation assessment in Bangladesh. Climate Res 12(2/3):109–116 (CR Special 6). Available at: http://www.intres.com/articles/cr/12/c012p109.pdf

Arnell NW, Bates BC, Lang H, Magnuson JJ, Mulholland P (1996) Hydrology and freshwater ecology. In: Watson RT, Zinyowera MC, Moss RH (eds) Climate change 1995: impacts, adaptations, and mitigation of climate change: scientific-technical analyses. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 325–363

Bangladesh Bureau of Statistics (BBS) (1998) Statistical yearbook of Bangladesh. Bangladesh Bureau of Statistics, Dhaka

Barnett J (2007) The geopolitics of climate change. Geogr Compass 1:1361–1375. doi:10.1111/j.1749-8198.2007.00066.x

Bates BC, Kundzewicz ZW, Wu S, Palutikof JP (eds) (2008) Climate change and water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 p

BCAS and Approtech (1994) Vulnerability of Bangladesh to climate change and sea level rise. Concepts and tools for calculating risk in integrated coastal zone management [Report].

Bangladesh Centre for Advanced Studies (BCAS), Dhaka and Resource Analysis (RA), and Approtech Consultants Limited, Delft.
Brammer et al (1996) Groundwater intensive use. In: Sahuquillo A, Capilla J, Martínez-Cortina L, Sánchez-Vila X (eds) IAH selected papers on hydrogeology, vol 7. Taylor & Francis 2005. pp 221–235. Print ISBN: 978-0-415-36444-7; eBook ISBN: 978-1-4398-3362-9; doi:10.1201/9781439833629.ch16
BRTC-BUET (2005) Final report of the Sectoral Working Group on Industry and Infrastructure. Bureau of Research, Testing and Consultation (BRTC), Bangladesh University of Engineering and Technology (BUET), Dhaka
BUP-CEARS-CRU (1994) Bangladesh: greenhouse effect and climate change. Briefing Documents No. 1-7. Bangladesh Unnayan Parishad (BUP), Bangladesh; Centre for environmental and Resource Studies (CEARS), University of Waikato, New Zealand and Climate Research Unit (CRU), University of East Anglia, Norwich
BWDB (2009) Predicting riverbank erosion along the Jamuna, Ganges and Padma Rivers for 2009 and 2010 and analysis for long-term bank erosion processes of the ganges and Padma Rivers under Jamuna-Meghna River Erosion Mitigation Project: ADB Loan No. 1941-BAN (SF). Centre for Environmental and Geographic Information Services (CEGIS)
CCC (2009) Impact assessment of climate change and sea level rise on monsoon flooding. Climate Change Cell, DoE, MoEF; Component 4b, CDMP, MoFDM. Dhaka
CEGIS (2006) Impact of sea level rise on landuse suitability and adaptation options. Ministry of Environment and Forest (MoEF), Dhaka
CEGIS (2010) Impact of climate change in river erosion. Dhaka, Bangladesh: Center for Environment and Geographic Information Services (CEGIS), Asian Development Bank
Farquharson F, Fung F, Chowdhury JU, Hassan A, Horsburgh K, Lowe J (2007) Impact of climate and sea level change in part of the Indian sub-continent (CLASIC). Center for Ecology and Hydrology-Natural Environment Research Council, UK
Faruque HSM, Ali ML (2005) Climate change and water resources management in Bangladesh. In: Mirza MMQ, Ahmad QK (eds) Climate change and water resources in South Asia. Balkema Press (Taylor and Francis), Leiden, pp 231–254
Faruquee R (ed) (1998) Bangladesh agriculture in the 21st century. University Press Limited, Dhaka
GoB (2007) Road Master Plan. Roads Division, Ministry of Communications; Government of People's Republic of Bangladesh (GoB)
Gordon ND, McMahon TA, Finlayson BL (1992) Stream hydrology: an introduction for ecologists. Wiley, Chichester, 526 pp
Habibullah M, Ahmed AU, Karim Z (1998) Assessment of foodgrain production loss due to climate induced enhanced soil salinity. In: Huq S, Karim Z, Asaduzzaman M, Mahtab F (eds) Vulnerability and adaptation to climate change for Bangladesh. Kluwer Academic, Dordrecht, pp 55–70
Hu Z-Z, Latif M, Roeckner E, Bengtsson L (2000) Intensified Asian summer monsoon and its variability in a coupled model forced by increasing greenhouse gas concentrations. Geophys Res Lett 27(17):2681–2684
IPCC (2000) EMISSIONS SCENARIOS (including Summary for Policymakers, which is available in Arabic, Chinese, English, French, Russian and Spanish). A special report of IPCC Working Group III, 2000. Cambridge University Press, Cambridge, p 375
IPCC (2001a) In: Houghton JT, Ding Y, Griggs DJ, Noguer M, van der Linden PJ, Dai X, Maskell K, Johnson CA (eds) Climate change 2001: the scientific basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge. ISBN 0521807670
IPCC (2001b) Climate change 2001. In: McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS (eds) Impacts, adaptation & vulnerability. Contribution of Working Group II to the Third Assessment Report of the IPCC. Cambridge University Press, Cambridge, 1000 pp
IPCC (2007a) Climate change 2007. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds) The Physical Science Basis. Contribution of Working

Group I to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge, 996 pp

IPCC (2007b) Climate change (2007). In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, 976 pp

Karim Z, Ibrahim AM, Iqbal A, Ahmed M (1990) Drought in Bangladesh agriculture and irrigation schedules for major crop. The Bangladesh Agricultural Research Council, Dhaka

Karim Z, Hussain SG, Ahmed M (1996) Assessing impacts of climate variations on foodgrain production in Bangladesh. Water Air Soil Pollut 92:53–62

Karim Z, Hussain SG, Ahmed AU (1998) Climate change vulnerability of crop agriculture. In: Huq S, Karim Z, Asaduzzaman M, Mahatab F (eds) Vulnerability and adaptation to climate change for Bangladesh. Kluwer, Dordrecht, pp 39–54

Kattenberg A, Giorgi F, Grassl H, Meehl GA, Mitchell JFB, Stouffer RJ, Tokioka T, Weaver AJ, Wigley TML (1996) Climate models—projections of future climate. In: Houghton JT, Filho LGM, Callandar BA, Harris N, Kattenberg A, Maskell K (eds) Climate change 1995: the IPCC second assessment. Cambridge University Press, Cambridge, pp 285–358

Lal M, Meehl GA, Arblaster JM (2000) Simulation of Indian summer monsoon rainfall and its intraseasonal variability. Reg Environ Change 1(3/4):163–179

Leytham M (2010) Technical memorandum to provide an assessment of future climate, river and ocean conditions for the proposed Padma Bridge at Mawa (as a part of contribution to the Environmental Impact Assessment Report of Padma Multipurpose Bridge Design Project). Dhaka, Bangladesh: Bangladesh Bridge Authority

McGuffie K, Henderson-Sellers A, Holbrook N, Kothavala Z, Balachova O, Hoekstra J (1999) Assessing simulations of daily temperature and precipitation variability with global climate models for present and enhanced greenhouse climate. Int J Climatol 19(1):1–26

Miller KA, Rhodes SL, MacDonnel LJ (1997) Water allocation in a changing climate: institutions and adaptation. Climatic Change 35:157–177

Milliman JD, Broadus JM, Gable F (1989) Environmental and economic implications of rising sea level and subsiding deltas: the Nile and Bengal examples. Ambio 18(6):340–345

Ministry of Environment and Forest (MoEF) (2002) Initial National Communication under the United Nations Framework Convention on Climate Change (UNFCCC). Ministry of Environment and Forest (MoEF), Government of the People's Republic of Bangladesh, Bangladesh Secretariat, Dhaka

Mirza M, Warrick RA, Ericksen NJ, Kenny GJ (2001) Are floods getting worse in the Ganges, Brahmaputra and Meghna basins? Global Environmental Change Part B: Environmental Hazards, 3(2):37–48

Mirza M (1997) Modeling the effects of climate change on flooding in Bangladesh. International Global Change Institute (IGCI), University of Waikato, Hamilton

Mirza MM, Ahmed QK (2005) Climate change and water resources in South Asia: an introduction. In: Mirza MM, Ahmed QK. Climate change and water resources in South Asia (pp. 23–54). Leiden, The Netherlands: A.A. Balkema Publishers

Mirza MQ, Dixit A (1997) Climate change and water management in the GBM basins. Water Nepal 5(1):71–100

NAPA (2005) National Adaptation Programme of Action (NAPA) Final Report. Ministry of Environment and Forest, Government of the People’s Republic of Bangladesh, Dhaka

Nizamuddin K, Khuda ZRMM, Ahmad N (2001) Women-headed households displaced by River Bank erosion: problems and strategies of survival. In: Nizamuddin K (ed) Disaster in Bangladesh: selected readings. Disaster Research Training and Management Centre, Dhaka, pp 49–60

Nychka D, Restrepo JM, Tebaldi C (2009) Uncertainty in climate predictions. American Mathematical Society, Providence

Parry ML, Fischer C, Livermore M, Rosenzweig C, Iglesias A (1999) Climate change and world food security: a new assessment. Global Environ Change 9:S51–S67

Roeckner E, Bengtsson L, Feichter J, Lelieveld J, Rodhe H (1999) Transient climate change simulations with a coupled atmosphere–ocean GCM including the tropospheric sulfur cycle. J Climate 12:3004–3032

Rosenzweig C, Iglesias A, Yang XB, Epstein PR, Chivian E (2001) Climate change and extreme weather events: implications for food production, plant diseases and pests. Global Change Hum Health 2:90–104

Siddiqi MH (1997) Floods: problems and prospects. Paper presented at the Workshop on observance of the International Decade for Natural Disaster Reduction 1997, Organized by the Disaster Management Bureau, Ministry of Disaster Management and Relief, The Government of the People's Republic of Bangladesh (GoB), Dhaka, 8 October 1997

Siddique QI, Chowdhury MMH (2000) Flood '98: losses and damages. In: Ahmad QK et al (eds) Perspectives on flood 1998. The University Press Limited (UPL), Dhaka, pp 1–13

Tanner T, Hassan A, Islam K, Conway D, Mechler R, Ahmed A et al (2007) ORCHID: piloting climate risk screening in DFID Bangladesh (detailed research report). Institute of Development Studies, University of Sussex, Sussex

United Nations Environment Programme (UNEP) (1989) Environmental data report. GEMS Monitoring and Assessment Research Centre. Basil Blackwell, United Nations Environment Programme (UNEP), Oxford, 1993–1994

US Global Change Research Program (2000) Water: the potential consequences of climate variability and change for the water resources of the United States. National Water Assessment Group, U.S. Global Change Research Program, p 160. http://www.gcrio.org/NationalAssessment/water/water.pdf

Walker B, Steffen W (1997) An overview of the implications of global change for natural and managed terrestrial ecosystems. Conserv Ecol 1(2):2 [online]. Available from the Internet: http://www.consecol.org/vol1/iss2/art2

WARPO (1999) National Water Management Plan Project. Ministry of Water Resources, Govt. of Bangladesh, Dhaka

WARPO (2001) National Water Management Plan. Water Resources Planning Organization, Ministry of Water Resources, Government of the People's Republic of Bangladesh, Dhaka

WARPO (2005) Impact assessment of climate change on the coastal zone of Bangladesh. Water Resources Planning Organisation, Ministry of Water Resources, Dhaka

WB (2000) Bangladesh: climate change and sustainable development. Report No. 21104-BD. Rural Development Unit, South Asia Region, The World Bank (WB), Dhaka, p 95

Whetton PH, Fowler AM, Haylock MR, Pittock AB (1993) Implications of climate change due to the enhanced greenhouse effect on floods and droughts in Australia. Climatic Change 25:289–317

World Bank (2010) Economics of adaptation to climate change. World Bank, Washington, DC

WRI (World Resources Institute) (1998) World resources 1998–99. Oxford University Press, New York

Chapter 3
Sea Level Rise and Its Impacts in Coastal Areas of Bangladesh

Ainun Nishat and Nandan Mukherjee

Abstract Sea level rise due to sedimentation, although significant near river deltas, is negligible on a global scale. Sea level rise (SLR) on a short time scale (several years) is associated with El Nino/Southern oscillations. Bangladesh is highly vulnerable to sea level rise, as it is a densely populated coastal country of smooth relief comprising broad and narrow ridges and depressions. A big chunk of the fresh-water zone that will be disappearing due to sea level rise near to the estuary will have a far reaching effect on the country's ecology and will extinct some of its endangered species. The southwest region of Bangladesh comprises the world's largest single track of mangrove forest—the Sundarbans, which is also vulnerable to the sea level rise. It is located at the southern extremity of the Ganges river delta bordering the Bay of Bengal. A possible 45 cm sea level rise by the year 2050 could inundate 75 % of the Sundarbans. Several studies are initiated to find out suitable adaptation measures that have the potential to help farmers adapt to climate changes and to identify suitable varieties of crops that would be able to adapt to climate change. One of them is a study titled "Adaptive Crop Agriculture Including Innovative Farming Practices in the Coastal Zone of Bangladesh," which was conducted in Satkhira, a coastal district of Bangladesh.

Keywords Climate change • Coastal livelihood • Mangrove forest • People's livelihoods • Sea level rise

A. Nishat (✉) • N. Mukherjee
BRAC University, Dhaka, Bangladesh
e-mail: ainunnishat@yahoo.com

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*, Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_3, © Springer Japan 2013

3.1 Introduction

A number of previously published studies examined the potential impacts of climate change on Bangladesh (e.g., Qureshi and Hobbie 1994; Huq et al. 1996, 1999; Warrick and Ahmad 1996), assuming certain changes in the climate and corresponding sea level rise. Islam (2001) identified some of the changes in global mean sea level induced by several processes on different time and space scales. The processes include glacio-isostatic rebound, oceanographic, atmospheric, and tectonic effects. Estuatic sea level variation is associated with the volume change of seawater and relative sea level rise can be different due to local uplift and subsidence. Sea level rise due to sedimentation, although significant near river deltas, is negligible on a global scale. Sea level rise (SLR) on a short time scale (several years) is associated with El Nino/Southern oscillations.

Future climate change scenarios research by a pilot study of Department of Environment mentioned (DOE 1993) a potential future sea level rise for Bangladesh is 30–50 cm by 2050. Ahmed and Alam (1998) has projected the SLR value for the year 2030 and 2050, which have been constructed by using general circulation models (GCM) that was superimposed on long-term climatic patterns over ten locations in Bangladesh. Their estimate was 1-m change of sea level by the middle of twenty-first century; it combines a 90 cm rise in sea level and about 10 cm local rise due to subsidence. The SAARC Meteorological Research Centre (SMRC) analyzed sea level changes of 22 years historical tide data at three tide gauge locations in the coast of Bangladesh. The study revealed that the rate of sea level rise during last 22 years is many fold higher than the mean rate of global sea level rise over 100 years. SMRC projected figures of sea level rise are 18, 30 and 60 cm for the year 2030, 2050 and 2100 respectively. National Adaptation Programme for Action (GOB 2005) Team is fully compliant with the Third Assessment Report (TAR) of IPCC regarding probable SLR, which indicates that the global sea level rise is 9–88 cm from 1999 to 2100. According to the fourth assessment report of IPCC (IPCC 2007, Table 10.7), it is projected that the highest amount of global average sea level rise during the twenty-first century in the range 0.26–0.59 m. Another consideration of local sea level rise in the Bay of Bengal is expected to be between 0.0 and 0.05 m (IPCC 2007, Fig. 10.32). But it should be noted that the IPCC rates of change of sea level are only indicative and accurate predictions could not be made due to inherent weaknesses of the models. In addition to this, there is a wide range of variation concerning the extent of such changes in the above-mentioned and other literatures (Yohe and Schlesinger 1998; Hare 1999) Moreover, IPCC's Fourth Assessment report has been criticized for essentially discounting recent observations of substantial ice losses from the Greenland and Antarctic ice sheets in its projections of future sea level rise. Mote et al. (2008) provides a rough estimate of an upper limit for ice sheet loss contributions to global sea level rise of 0.34 m by 2100.

There are several aspects of sea level rise in Bangladesh. This brief chapter has three sections: observed seal level rise in Bangladesh, salinity intrusion and impacts on Sundarban. Finally, a brief example is provided on the adaptation in agriculture sector in coastal areas. Beside these issues, there are serious impacts on coastal agriculture and coastal livelihoods, which are discussed in other chapters of this book.

3.2 Observed Sea Level Rise in Bangladesh

Bangladesh is highly vulnerable to sea level rise, as it is a densely populated coastal country of smooth relief comprising broad and narrow ridges and depressions (Brammer et al. 1993). A study by SAARC Meteorology Research Centre (SMRC, cited in Alam 2003) found that tidal level in Hiron Point, Char Changa and Cox's Bazar raised 4.0, 6.0 and 7.8 mm/year respectively, observing tidal gauge record of the period 1977–1998. They have also mentioned that the rate of the tidal trend is almost double in the eastern coast than that of the western coast. This difference could be due to subsidence and uplifting of land.

In the South West region at Hiron point station the mean annual change in water level has been found as 5.5 mm/year (Fig. 3.1 and Table 3.1). Maximum rise in the water level is observed in the South East region at the Maheshkhali station which is 7.4 mm/year followed by 7.04 mm/year in the Sandwip and 5.05 mm/year in the Cox's Bazar stations. But in the Maheshkhali and Sandwip area, tidal process has been perturbed due to continuing morphological dynamism, tidal amplification or dampening due to natural accretion and formation of new funnel shaped chars and islands and also due to several other human interventions like cross-dam

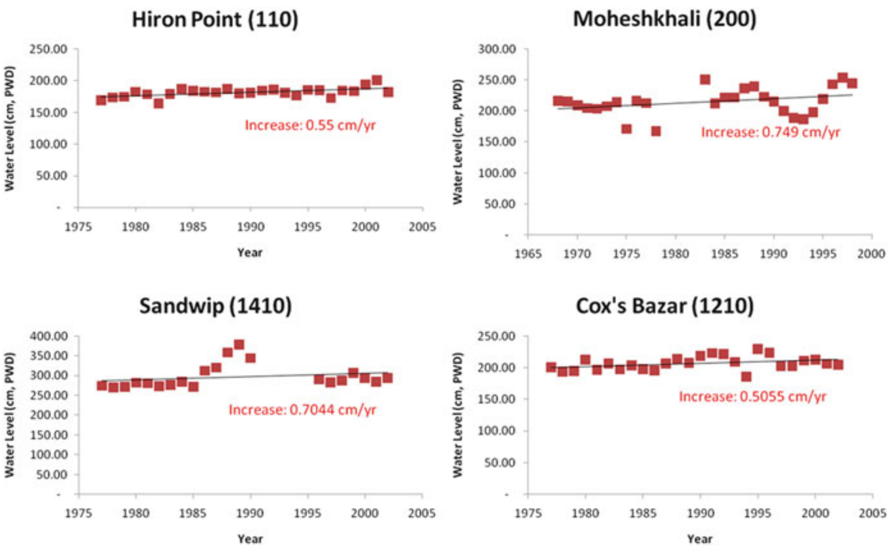


Fig. 3.1 Observed trend in sea level rise as evident from different tidal stations along the coast

Table 3.1 Periodic analysis of observed sea level rise at different tidal water level stations

	Observed water level (m, PWD)			
Period of analysis	Hiron Point	Moheshkhali	Cox's Bazar	Sandwip
1968–1977		207.10		
1977–1986	177.35	214.35	199.87	279.31
1987–1996	182.76	214.97	213.68	337.75
1997–2002	186.20		206.54	291.29
Change in the mean sea level (from trend line)	0.55 cm/year	0.749 cm/year	0.5055 cm/year	0.7044 cm/year

Table 3.2 High end [*top*], low end [*middle*] and pragmatic range [*below*] estimate of sea level rise

Global sea level rise (IPCC 2007)	0.59 m
Additional ice sheet contribution (Mote et al. 2008)	0.34 m
Local sea level rise (IPCC 2007)	0.05 m
Total	0.98 m
	0.26 m
Global sea level rise (IPCC 2007)	
Additional ice sheet contribution (Mote et al. 2008)	0.00 m
Local sea level rise (IPCC 2007)	0.00 m
Total	0.26 m
A pragmatic mid-range estimate of sea level rise would be:	
Global sea level rise (middle of AR4 A1F1 range)	0.43 m
Additional ice sheet contribution	0.17 m
Local sea level rise	0.00 m
Total	0.60 m

implementation. In the south western (Sundarban) and south eastern part (Cox's Bazar), the observed change in sea level is mostly free from any sort of artificial or man-made interventions and thus the most reliable estimate of mean sea level rise can be taken from the remaining two stations. Here it is notable that the mean sea level is rising and observed range of sea level variance can be taken as 5.05 mm to 7.4 mm/year.

Bangladesh has 710 km long coastline. The landward distance of the delineated coastal zone from the shore is between 30 and 195 km whereas the exposed coast is between 37 and 57 km. Other part of the country has an elevation of less than 10 m above sea level. With the exception of the Chittagong Hill Tracts in the southeast and the Modhupur tract in the central region, the country is located in the floodplains of three main rivers namely Ganges, Brahmaputra and Meghna. The coastal zone is low-lying with 62 % of the land have an elevation of up to 3 m and 86 % up to 5 m. From the available information, three alternative sea level rise scenario can be proposed as shown in Table 3.2.

Here it is also to be noted that the recommended value for sea level rise of 0.60 m is, coincidentally, at the top end of the range for global sea level rise under the AR4 A1F1 scenario of 0.59 m and the observed mean sea level is also around 0.55 cm per year.

Lesson Learnt from the Investigating the Impact of Relative Sea-Level Rise on Coastal Communities and Their Livelihoods in Bangladesh

CEGIS and IWM were partners in carrying out the study on impacts on sea level, funded by UK Department for Environment Food and Rural Affairs. The potential impact of sea level rise along Bangladesh coast provide an information about the land which could be inundated and the population that would be affected provided no adaptive/protective measures are taken. During monsoon, the result shows that in the year 2080 at 62 cm sea level rise for high emission scenario (A2 scenario), an additional area of 4,69,000 ha (13 % of land area of coastal region) will be remain inundated compared to the base condition of year 2005. The most vulnerable areas along the Bangladesh coastline are the areas without polders like Patuakhali, Pirojpur, Barisal, Jhalakati, Bagerhat. Increase in rainfall (10 % increase in rainfall within Bangladesh) in addition to 62 cm sea level rise in 2080 will increase the permanent inundated area by 16 % (5,515,000 ha) in the monsoon. The following figure shows the inundation of the coastal region of Bangladesh for 15 cm (B1 scenario), 27 cm (A2 scenario) and 62 cm (A2 scenario) sea level rise during monsoon.

On the contrary, in the dry season due to 62 cm sea level rise about 364,200 ha (10 %) more area will be inundated (inundation more than 30 cm) for A2 scenario in the year 2080. However, 15 cm sea level rise has insignificant impact on inundation in dry season.

In the Meghna estuarine zone, at Daulatkhan in Shahabazpur channel, result shows that high tide is found to increase by 30 cm and 80 cm for 32 cm and 88 cm sea level rise respectively. Sea will enter more and at Chandpur water will rise by 50 cm for 88 cm rise of sea level and 15 cm for 32 cm rise of sea level. Figures in Annex B are the inundation depth for different range of water depth in the southwest, southeast and Meghna Estuary.

3.3 Salinity Intrusion

A big chunk of the fresh-water zone that will be disappearing due to sea level rise near to the estuary will have a far reaching effect on the country's ecology and will extinct some of its endangered species (marked by IUCN) forever. Bangladesh's NAPA document has also highlighted the concerns regarding salinity ingress, especially for the southwestern region (GOB 2005). The world heritage and declared Ramsar site Sundarban will be hugely affected by the salinity ingress. Actually, the Sundarbans has already been affected due to reduced freshwater flows through Ganges river system over the last few decades particularly during the dry season. This has led to a definite inward intrusion of the salinity front causing the different species of plants and animals to be adversely affected. Increased salt-water intrusion is considered as one of the causes of top dying of Sundari trees. The impact of sea level rise will further intrude the saline water to landward. Sea level rise of 32 cm will intrude 10–20 ppt salinity level more in the Sundrabans.

3.4 Impacts on the Sundarbans

The southwest region of Bangladesh comprises the world's largest single track of mangrove forest—the Sundarbans. It is located at the southern extremity of the Ganges river delta bordering the Bay of Bengal. The mangrove forest extends 80 km inland from the coast and is bounded on the east by the *Baleswar* river and on the west by the Ichamati–Raimongal river. The Sundarbans alone constitute 40 % of the forest lands under the jurisdiction of the Forest Department and 24 % of the total forest area of Bangladesh. Its area is 577,100 ha (6,017 km^2) including 407,100 ha of mangrove forest and 170,000 ha of river channels, canals and creeks.

The topographical distribution of Sundarbans varies from 0.5 to 4.0 m with respect to PWD datum. Inside the Sundarbans the tidal fluctuation ranges from 1.5 to 2.5 m. Approximately 70 % of the land lies between 1.5 and 3.0 m elevation, which goes under water in regular tidal flooding twice a day. But almost 85 % of the land goes under water during high tide in the monsoon season.

The Sundarbans was declared a reserved forest in 1878 and provisions of the Forest Act of 1927 are applicable to this area. There are three wildlife sanctuaries comprising 23 % of the Sundarban Reserve Forest (SRF) in the southern part, which was declared a world heritage site in 1997. The natural vegetation of the Sundarbans is composed mainly of halophytic tree species. The forest canopy is seldom more than 10 m above ground level and is more or less open, permitting some direct sunlight to reach the forest floor. Much of the forest is two-storied with scattered emergent's attaining a height of up to 20 m. Stem diameters are generally less than 30–40 cm at breast height, although one or two species attain diameters up to about 1 m. Epiphytes are common, so too are woody species parasitic on tree crowns (IUCN 1994). The trees of the Sundarbans exhibit hydrophytic and halophytic adaptations, which facilitate survival in waterlogged and saline conditions. Three ecological zones within the Sundarbans, differentiated according to salinity and species composition, are: (1) the freshwater zone, (2) the moderately saltwater zone and (3) the saltwater zone.

Sea level rise poses a severe threat to the Sundarbans. A possible 45 cm sea level rise by the year 2050 could inundate 75 % of the Sundarbans(Qureshi and Hobbie 1994). While the sea level rise may be counterbalanced by natural uplift, the extent of uplift is highly uncertain. It is also reported that, climate change induced higher evapo-transpiration, and low flow in winter would increase salinity. As a result, growth of fresh water loving species would be impaired. Eventually, the species offering dense canopy cover would be gradually replaced by non-woody shrubs and bushes. It is also feared that the overall productivity of the forest would decline significantly (Ahmed and Alam 1998). Once the quality of the forest is degraded, one may conclude that the rich diversity of forest flora and fauna would also face degradation in a warmer world. The Sundarbans is home to the Royal Bengal tiger as well as marine turtles, crocodiles, frogs, and fresh water dolphins. With the loss of the Sundarbans, habitat for these species would also be lost. Whether these valuable species could survive elsewhere is not known.

3.5 Adaptation Practice in Coastal Agriculture

Several studies are initiated to find out suitable adaptation measures that have the potential to help farmers adapt to climate changes and to identify suitable varieties of crops that would be able to adapt to climate change. One of them is a study titled "Adaptive Crop Agriculture Including Innovative Farming Practices in the Coastal Zone of Bangladesh," which was conducted in Satkhira, a coastal district of Bangladesh. It was conducted in partnership with Bangladesh Rice Research Institute, Bangladesh Agriculture Research Institute, Bangladesh Agriculture Research Council and Bangladesh UnnayanParishad. In order to assess and analyze the problems, the study team members appraised the existing findings from literature review and community consultation. An attempt was made to understand the present and future geo-physical environment of the study area. The CROPSUIT model developed by CEGIS was used to estimate the physical suitability of land for different types of land uses or crop cultivation. Physical suitability change under climate change scenarios was analyzed to assess potential threats to current landuse practices.

From field experiments it was found that introduction of high yielding salt tolerant variety *BRRIdhan47* could produce sustainable grain yield in the coastal regions. It was also observed that there was no salinity impact on rice production due to high rainfall during monsoon season. But in the later part, when the rainfall ceases, it was assumed that soil salinity might increase and go beyond the safe limit of rice crop (4 dS/m). So, salt tolerant *T. Aman*varieties like *BR23*, *BRRIdhan40* and *BRRIdhan41* may be the solution to overcome salinity impact at the later stage. *Tomato*, *okra* and *aroid* were grown successfully under improved management practices with raised bed and mulch in the medium saline soils of Satkhira. The existing cropping pattern of *Fallow–T.Aman*(Local)–*Fallow* or *Fallow–T.Aman*(Local)–*Boro*(Local/HYV) may be replaced with the pattern of *Okra* (*Dharosh*)–*T.aman–Boro*(HYV) or *Okra* (*Dharosh*)–*T.aman–Tomato*. It is difficult to confirm a crop as adaptive under climate change situations using only one season crop related data. At least 3 years of experimentation will be needed to confirm whether a crop is adaptive under climate change situations in the coastal region. The adapted rice and non-rice crop results along with their innovative farming practices may be expanded throughout the salt affected coastal zone of Bangladesh.

Several other chapters in this book also describe innovative practices in coastal agriculture, coastal habitat and other livelihood related issues. The readers are encouraged to read those chapters in connection to this sea level rise chapter.

References

Ahmed AU, Alam M (1998) Development of climate change scenarios with general circulation models. In: Huq S, Karim Z, Asaduzzaman M, Mahtab F (eds) Vulnerability and adaptation to climate change for Bangladesh. Kluwer Academic, Dordrecht, pp 13–20

Alam M (2003) Bangladesh country case study. In: National Adaptation Programme of Action (NAPA) Workshop, 9–11 September 2003, Bhutan

Brammer H, Asaduzzaman M, Sultana P (1993) Effects of climate and sea-level changes on the natural resources of Bangladesh. Briefing Document No. 3, Bangladesh Unnayan Parishad (BUP), Dhaka

Department of Environment (1993) Assessment of the vulnerability of coastal areas to climate change and sea level rise. A pilot study of Bangladesh. Department of Environment, Ministry of Environment and Forest (MoEF), Government of the People's Republic of Bangladesh (GoB); Bangladesh Center for Advanced Studies (BCAS); Resource Analysis (RA); and Approtech, Dhaka

Hare B (1999) Fossil fuels and climate protection: the carbon logic. Greenpeace International, Amsterdam

Huq S, Ahmed AU, Koudstaal R (1996) Vulnerability of Bangladesh to climate change and sea level rise. In: Downing TE (ed), Climate Change and World Food Security, NATO ASI Series, I 37, Springer-Verlag, Berlin, Hiedelberg, pp 347–379

Huq S, Karim Z, Asaduzzaman M, Mahtab F (1999) Vulnerability and adaptation to climate change in Bangladesh. Dordrecht: Kluwer

IPCC (2007) Impacts, adaptation and vulnerability. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Contribution of Working Group II to The Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

Islam MS (2001) Sea level changes in Bangladesh: the last ten thousand years. Asiatic Society of Bangladesh, Dhaka

IUCN (1994) In: Hussein Z, Acharya G (eds) Mangroves of the Sundarbans. IUCN, Gland

Mote PW, Hamlet AF, Clark MP, Lettenmaier DP, Salathé E (2008) Has spring snowpack declined in the Washington cascades? Hydrol Earth Syst Sci 12:193–206

NAPA (2005) National Adaptation Programme of Action (NAPA) Final Report. Ministry of Environment and Forest, Government of the People's Republic of Bangladesh, Dhaka

Qureshi A, Hobbie D (1994) Potential impacts of climate change in Bangladesh. In: Asian Development Bank (ed) Climate change in Asia. Asian Development Bank, Manila, pp 10–42 (Chapter 2). http://www.adaptationlearning.net/profiles/country/files/WorldBank_Climate%20change%20impacts%20in%20Bangladesh.pdf

Warrick A, Ahmad QK (1996) The implications of climate and sea-level change for Bangladesh. Kluwer Academic, Dordrecht

Yohe GW, Schlesinger ME (1998) Sea level change: the expected economic cost of protection of abandonment in the United States. Clim Chang 38(4):447–472

Chapter 4
Urban Poverty, Climate Change and Health Risks for Slum Dwellers in Bangladesh

Sabina Faiz Rashid, Showkat Gani, and Malabika Sarker

Abstract The health and rights of populations living in urban slum settlements against the backdrop of increasing risks and disasters brought on by climate change is a key development issue of the twenty-first century. The impacts of natural hazards as a result of climate change are unevenly distributed globally and nationally, with populations in mega cities most vulnerable. Bangladesh remains riskiest on the global climate index and was recently ranked as one of the top countries most affected by extreme weather events according to recent news report. Dhaka has a high vulnerability of climate change as well as urban poverty. Slums settlements tend to be located in low lying land areas that are flood prone. A spatial mapping of approximately 7,600 households in 44 slum settlements was found to be within 50 m of a river and risked being flooded. In urban slums, it was found that when water started pouring in, some families built bamboo platforms and shifted their belongings on it. In some cases, families raised their beds by putting bricks under it to raise the level of the beds. In some cases, families shifted to the roofs of their homes, if the roofs were sturdier. The situation from urban poor is dismal due to the overcrowding and lack of access to basic services, such as water and sanitation. Consequences of these living conditions include stress due to crowding, insecurity due to lack of housing and land tenure. These conditions worsen during floods and disasters. The absence of clear and forward-looking policies on urbanization and urban slum settlements discourages long-term thinking and interventions to improve the long-term prospects of people who live in slum settlements.

Keywords Climate change • Health vulnerability • Poverty • Sanitation • Urbanization

---

S.F. Rashid (✉)
James P Grant School of Public Health, BRAC University, Dhaka, Bangladesh
e-mail: sabina@bracu.ac.bd

S. Gani • M. Sarker
BRAC University, Dhaka, Bangladesh

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*, Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_4, © Springer Japan 2013

4.1 Introduction

The health and rights of populations living in urban slum settlements against the backdrop of increasing risks and disasters brought on by climate change is a key development issue of the twenty-first century. According to the Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC) in 2007, average global temperatures have increased by 0.74 °C in the last 100 years, and the sea level rise has increased in the last decade to 3.1 mm/year compared to 1.8 mm/year for previous years (IPCC 2007). The world is entering a historic urban transition and in the last half century, the world's urban population has increased nearly fourfold, from 732 million in 1950 to more than 3.2 billion in 2006. For the first time in history of the world, more people live in cities than in rural areas (Schlein and Kruger 2006). Africa now has 350 million urban dwellers, more than the population of Canada and the United States combined. Asia and Africa are expected to double their urban populations to roughly 3.4 billion by 2030 (WWI 2007). The "mega cities (more than 10 million population)" of the developing world with their rapid urbanization, increasing populations and growth in slum settlements can be at significant risk from extreme weather conditions, earthquakes, flashfloods, droughts, tsunamis, landslides, cyclones and other natural disasters (Megacities 1995).

Slums in poor cities are growing by 100,000 people per day—one person every second (CARE). Rural to urban migration, combined with natural population growth in urban areas, creates enormous, often unmet, demand for housing, services, transport, and work, creating shack and slum settlements mushrooming in cities all over the world (Friel et al. 2008). There are now at least 750 million people living in urban squatter settlements without adequate shelter or basic services and without legal title to their land. The numbers of people living in these settlements is expanding so rapidly that governments are unable to keep up with the necessary infrastructure development and services like water and sanitation are woefully inadequate. The lack of legal recognition means not the absence of basic services and often basic rights, resulting in health risks and vulnerabilities (Vlahov et al. 2007).

The impacts of natural hazards as a result of climate change are unevenly distributed globally and nationally, with populations in mega cities most vulnerable. By 2015 there will be 33 mega-cities with populations over 8 million; 28 in developing countries and 21 are in coastal locations (Kreimer et al. 2003). In this paper, we examine the interrelations between urban poverty, climate change and resulting risks and health vulnerabilities for poor urban slum populations in Dhaka, Bangladesh.

Dhaka, the capital city is projected to become the fourth largest city with 22 million population in the world by 2025, due to its rapid urban migration and growth in urban slum populations (Table 4.1: UN 2007; ICDDR and ACPR 2008). Dhaka has grown from a 2.2 million population in 1975, to 13.5 million in 2007. This fast-paced growth has resulted in widespread urban poverty—25 % of the urban population lives in urban settlements of which one-third is urban slums (UN 2007). A majority of the slum settlements tend to be located in low-lying, flood prone areas,

Table 4.1 Population trend of Bangladesh and Dhaka city, 1974–2025

Census year	1974	1981	1991	2001	2007	2011	2025
Bangladesh population size (million)	71.5	87.1	106.3	124.4	–	142.3	188.1[a]
Average annual growth rate %	–	2.32	2.01	1.58	–	1.34	1.34
Dhaka Urban population size (million)	2.2				13.5		22.0
Average annual growth rate %					5.64[b]		2.72[b]

Sources: 2011 Population & Housing Census: Preliminary Results; World Urbanization Prospects: The 2007 Revision, p. 11

[a]Projected population

[b]Average annual growth rates for the year 1975–2007 and 2007–2025 respectively

with poor drainage, limited formal garbage disposal and minimal access to safe water and sanitation and services, and face unimportance by the State. The conditions of high population density and poor sanitation exacerbate the spread of disease and other kinds of vulnerability particularly during disasters (Rashid 2000).

In Bangladesh, discussions and research on climate change and its impact on cities and urban poor populations remain a new area of research and little is known. While these statistics are useful to indicate the importance of climate change, local policymakers require more concrete information at the local level, such as, indicators to measure the impact of various natural hazards, disaster risk management and the public health risks associated with changes in temperature and precipitation and incidences of asthma, malaria and other waterborne diseases, and other social and economic impacts due to flooding and lack of proper drainage and sanitation facilities. Presently all of the major urban centers of the country have slum and squatter settlements, with the largest concentrations being in Dhaka with 4,966, followed by Chittagong 1,814, Khulna 520, Sylhet 756 and Rajshahi 641 slums and the rest are scattered throughout the country (Islam et al. 2006). In comparison to rural areas of the country, documentation on the lives of urban poor populations has been less rigorous and scanty. Viewed as “illegal settlers” by the government; there has been an overall neglect and exclusion of urban slum populations from long-term baseline studies, with few in-depth documentation of their needs, health and status. Drawing on the literature available, the paper will provide an insight into the growth of urban settlements, the resulting risks of climate change faced by urban slum populations who cope with floods and other kinds of disruptions, given their marginal status. It hoped that the paper will contribute to any steps government and agencies can take to reduce risks and thereby develop better planning to mitigate the effects of climate change on urban slum populations (Megacities 1995).

The chapter is structured into three main sections; the first section deals with climate change and the situation in Bangladesh; the second section describes the growth of urban slum settlements and their marginalized status, and the final section draws on secondary data to share stories of urban families who suffer from increasing flood risks due to climate change.

4.2 Climate Change

There are extreme climate changes occurring in Asia with temperatures rising and heat waves recorded in China, Russia, Mongolia, Korea, Japan, India and South East Asia. There have been increased and erratic rainfall induced frequent floods in Bangladesh, India, China and South East Asia. Cyclones and typhoons have affected Bangladesh, India, Philippines, Japan and China. Sea level rise and increased salinity are occurring in Bangladesh, India, Maldives, Sri Lanka, Indonesia and South East Asia. Droughts have affected South Asia including India and Bangladesh, as well as China and Mongolia. It is reported that the number of recorded disasters doubled globally from approximately 200 to over 400 per year in the past two decades, with nine out of 10 disasters now viewed as climate related (Mallick 2008).

The environmental and health outcomes of climate change impact unequally across regions and populations. In 2000, climate change accrued to that point causing a conservative estimate of 150,000 deaths. Although the poorest one billion people account for around 3 % of the world's total carbon footprint, the deaths were almost entirely confined to the world's poorest populations (Mallick 2008). The irony is that the vast majority of the people at risk have contributed almost nothing to the ongoing warming of the climate (Ali 1999).

Extensive climate changes may alter and threaten the living conditions of much of the world, with a sudden increase of large-scale migration because of climate induced human displacement. These may lead to greater competition for the earth's resources (land, water, agriculture, food, forest, biodiversity) particularly in the developing countries. Such changes place heavy burdens on the world's poor countries and most vulnerable communities (Mallick 2008).

In a series of articles published in *Environment and Urbanization*, the vulnerability of cities in relation to climate change is analyzed. It is predicted that the sea-level rise will create additional flooding risks for the 600 million people living in low-elevation coastal zones (Fig. 4.1). A high proportion of the urban population in low- and middle-income countries live within the Low-Elevation Coastal Zone (LECZ): the continuous area along the coast that is less than 10 m above sea level. Bangladesh is one of the nations with a large urban population in the LECZ.

Simulations by University of Middlesex, UK, suggest that South Asia will be massively affected, with up to 55 million people affected by flooding, if there is no change in their present levels of CO_2 emissions and atmospheric warming (Streatfield and Karar 2008 and no. 9). Higher temperatures will increase the risk of direct heat effects (heat stroke and reduced work ability due to heat). Urban air pollution will be exacerbated. This is truly an issue with major inequity consequences not only for health but for economic and social equity as well (Oxfam 2007). Among the consequences of a hotter climate, heat waves are an obvious concern. Poor people living in cities unable to afford air-conditioning as a means to reduce the health risks, while air-conditioning is in itself a contributor to the heat island effect and climate change. High temperatures will also jeopardize people's ability to carry out heavy

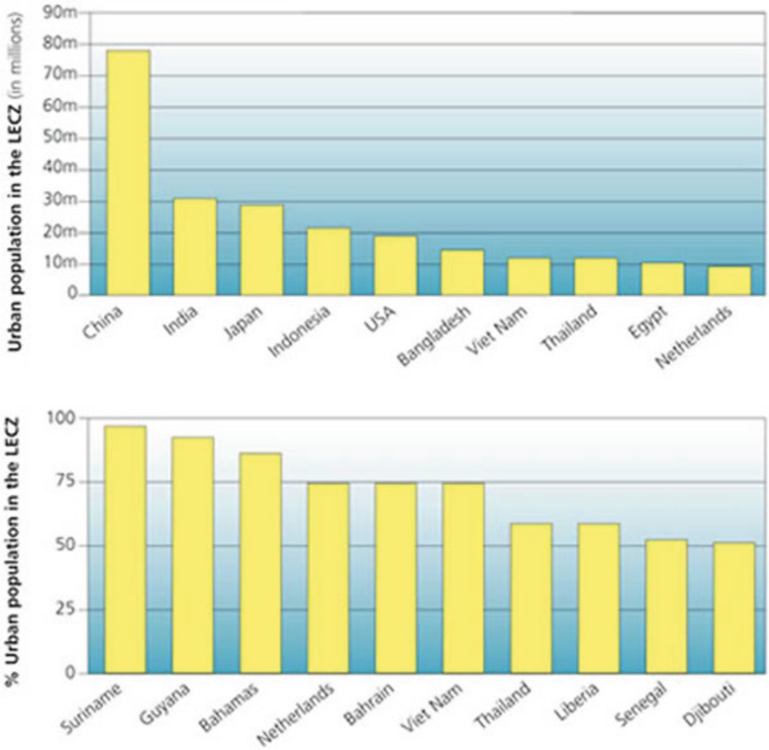


Fig. 4.1 People at risk in urban coastal zones. Nations with the largest urban populations in the LECZ. Nations with the highest proportion of their urban populations in the LECZ. *Source*: Satterthwaite et al. (2007)

work, which indirectly has negative effects on their income (Kjellstrom 2000; Hogstedt et al. 2007).

Bangladesh remains riskiest on the global climate index and was recently ranked as one of the top countries most affected by extreme weather events according to recent news report. The country was placed at the top of the position with a death toll of 4,729 in 2007 due to the natural calamities with an additional absolute loss of property worth more than $10 billion dollars (Germanwatch 2008). Bangladesh has faced extreme hazards with recent severe floods: 1988, 1998; 2004; and 2007; cyclones and tidal surges in 1991, 1998, 2000, 2004, 2007 (Table 4.2); and salinity and water logging in coastal zones and drought, heat stress and erratic and untimely rainfall (Mallick 2008).

The country is one of the most densely populated in the world and there is a high dependency on natural resources for subsistence, making Bangladeshis particularly vulnerable to climate shifts. Increased storm intensity could potentially worsen seasonal flooding that occurs in many parts of the country, while persistent drought is predicted in the North-West and rising sea levels may threaten low-lying coastal areas in the South if interventions are not forthcoming. These impacts may be exacerbated by demographic and social factors.

Table 4.2 Flood affected areas in major floods since the 60s (area of Bangladesh: 1,48,393 km²)

Year of flooding	Flood-affected area (km²)	% of total area
1954	36,780	24.8
1955	38,850	26.2
1974	52,520	35.4
1987	57,270	38.6
1988	77,700	52.4
1998[a]	1,00,000	67.4

[a] *Source*: GOB web site as of 26 September 1998 (http://www.bangladeshonline.com/gob/flood98)

Fig. 4.2 Korail Slum at Mohakhali of Dhaka City in Bangladesh (photo credit: Kim Streatfield)

In Bangladesh river erosion is believed to swallow nearly 25,000 acres (10,000 ha) each year, leaving some 60,000 people homeless. It is predicted to consume 3,575 km² by 2025. The Brahmaputra and Jamuna rivers alone are said to have contributed to one million rural inhabitants being driven into poverty, and forced to relocate, with the trend in recent decades of moving to cities in search of work (Streatfield and Karar 2008). It is predicted that over 35 millions will be climate refugees in Bangladesh by 2050 with increased rural-to-urban migration to cities, if flooding and drought make rural livelihoods less tenable.

Dhaka city remains extremely vulnerable. It is located between four flood-prone rivers in the most densely packed nation in Asia, and lies between the Himalaya mountain range and a body of water that not only generates violent cyclones and the occasional tsunami, but also moves further inland every year, washing away farmland, contaminating drinking water, submerging fertile deltas, and displacing villagers as it approaches. As a consequence, rural villagers migrate to Dhaka. It is estimated 300,000–400,000 migrants, mostly poor, arrive to the city annually (World Bank 2006) making Dhaka one of the world's largest megacities and also one of the most unplanned urban centres (Fig. 4.2).

Fig. 4.3 A small slum in Dhaka city as it sits precariously on the edge of a lake, and in contrast are some expensive apartment complexes (photo credit: Alayne Adams)

It is reported that the melting of glaciers and snow in the Himalayas, along with increasing rainfall attributable to climate change, will lead to more flooding in Bangladesh in general, especially in cities located near the coast and in the delta region, including Dhaka. Researchers studying the impact of climate change on Dhaka predict that the city will be affected primarily in two major ways: flooding and drainage congestion and heat stress. The elevation in Dhaka ranges between 2 and 13 m above sea level, which means that even a slight rise in sea level is likely to engulf large parts of the city. Moreover, high urban growth rates and high urban densities have already made Dhaka more susceptible to human-induced environmental disasters (UN Habitat 2009).

On arrival to Dhaka many rural migrants are unable to afford proper housing and turn to live slum settlements, on empty government or private land in congested crowded settlements, and remain vulnerable to sudden eviction by the government (Fig. 4.3). Viewed as "illegal residents" urban slum settlements are generally excluded from public sector resources, severely limiting residents' access to formal education, health care services and water and sanitation. Bangladesh does not have a comprehensive policy on urban slums. Implicit in the lack of urban policy in the country is the assumption that slum settlements are a transitory and passing phenomenon, something that can be remedied by programs for the rural poor to stem migration. This assumption has resulted in the denial of special programs for the urban poor and with the rate of urbanization increasing rapidly (Rashid 2009).

Slums settlements tend to be located in low lying land areas that are flood prone. A spatial mapping of approximately 7,600 households in 44 slum settlements was found to be within 50 m of a river and risked being flooded (Islam et al. 2006; World Bank 2006). Of the 9,048 slum settlements mapped by Islam et al., only 10 % had sufficient drainage to avoid water-logging during heavy rains (2006). The mapping also found that the problems associated with flooding are aggravated by poor quality housing and overcrowding. It was found that more than one-third of Dhaka's urban population lived in housing where almost all the structures were too weak to withstand large-scale environmental disasters. Although Bangladesh has among the highest population densities in the world (at 1,415 persons per km^2), the population density in slums is roughly 200 times greater and given that nearly all slums are mainly single-storey structures, this figure is shocking. Approximately 80 % of the slum population in Dhaka lives in dense slum clusters of between 500 and 1,500 persons per acre with more than 90 % of slum dwellers sharing a single room with three or more people (Islam et al. 2006).

In terms of employment the urban poor remain excluded mainstream job opportunities. They are mostly engaged in low paid, labor intensive work in the informal sector as they lack specific skills and unable to gain entry into the more competitive formal sectors of urban employment. A survey conducted in 2006 in Dhaka of 500 households in slum settlements found that 29 % of males pulled rickshaws (three wheeled bicycle taxis) in the city. Most rickshaw pullers tend to be illiterate and have no formal employment training. Another 23 % were involved in street peddling and petty trading (e.g. selling fruit/vegetables, towels, cheap merchandise, etc). The poor also worked in other occupations like construction work (6 %), driving and transport (5 %), garments and factory work (5 %) and domestic help (8 %). A much smaller portion had access to some education and worked in low grade government and semi-government institutions. Usually, the available low-skilled jobs are temporary; leaving the urban poor particularly vulnerable to fluctuations in the economy, and loss of work was one of the most devastating shocks they can face. In a survey of 500 households it was found that 35 % of people had been underemployed at least once during the survey year (Hossain 2006).

In terms of access to basic services, a review of the situation on health services for urban poor people who live in slum settlements found that only 7.3 % of slum settlements in Dhaka city have access to a public health clinic and only 26 % have a government school (World Bank 2006). The mapping of slums in the country found 70 % of slum settlements had no access to safe latrines. In nearly all slum settlements latrines were shared by a number of households, in half latrines were shared by at least 6 families (30 or more persons) (Islam et al. 2006). Another study reported out of 1,925 slum settlements identified, only 43 were within 100 m of a public toilet. One of the largest slum settlement, *Korail basti* in Banani, Dhaka city with more than 12,000 households did not have a single public toilet or health clinic (World Bank 2006). Problems of poor sanitation and drainage are endemic, and of the 9,048 slum settlements surveyed, 26.5 % had experienced full flooding during the rainy season (Islam et al. 2006).

A recent study indicates that slum settlements are growing at over 7 % per annum, implying a doubling time of less than a decade. The inevitable consequence of this situation will be urbanization on a scale which risks overwhelming the capacity of the urban authorities to provide housing, water and sanitation, healthcare, education, and other essential services to incoming migrants. Urban dwellers lack land to grow food, and are dependent on markets, but without an income, they cannot buy food. They also lack infrastructural support and resources and family support networks which they might have in a rural situation (Rashid 2005).

Streatfield and Karar review of studies on challenges of urbanization suggests that Bangladesh is close to the limits of availability of agricultural land and productivity (Streatfield and Karar 2008), at least in the short-term and with future rapid urban growth water is likely to be a limiting factor. While the recommended allowance of water is around 200 l/day per person (for all purposes), many slum-dwellers manage with less than 10 l/day. With the Dhaka population increasing by over 300,000 persons each year, theoretically needing six million additional liter per day, the numbers limited to this inadequate amount or less, will undoubtedly increase. The health implications are clear, where populations are growing, water is becoming increasingly scarce and sanitation is poor and not improving, water-borne diseases are very likely to become a serious problem again. In addition, air-borne diseases, such as influenza, pneumonia, and TB, all of which tends to be compounded by climate change (Streatfield and Karar 2008).

4.3 Slum Dwellers at Increased Health Risk in Bangladesh

Climate change increases both frequency and intensity of natural disasters. The negative consequences of climate change are likely to be felt especially by the urban poor who live in flood-prone and water-logged areas and remain neglected from government interventions. A rapid assessment on the impact of floods in 1998 by BRAC found that flooding was a major problem in a number of the slum settlements in Dhaka city, leaving thousands of families socially, economically and physically vulnerable and adversely affected. Climate changes are not only a destructive effective to slum dwellers, but also for the general population as whole. Recently Haque et al. (2012) had conducted a cross-sectional study among 450 senior household members (male/female ratio: 112.3) in two villages—one from the northern part (Rajshahi district) and other from the southern part (Khulna district) of Bangladesh. This study had reported that more than seven types of immediate problems from changes in heat and cold were due to changing of heat and cold were mentioned by respondents (Table 4.3), such as health and hygiene, production loss, working hour losses, poor crop growth and yield, over irrigation and increased illness incidence. Moreover, this study had also confirmed the most frequently reoccurred cold/cough/fever, dysentery, headaches, diarrhea, skin diseases, burning sensation, conjunctivitis, jaundice, blisters, asthma, pox, weight loss and pneumonia in relation to extreme and/or irregular patterns of heat, cold and rainfall. Similar data are missing in urban areas where the extreme cold and heat is highly prevalent.

Table 4.3 Perceived problems due to climate changes in rural two villages (i.e. extreme heat and cold, n=450)

Perceived problems due to extreme climate variability	Heat Yes (%)	Heat No (%)	Cold Yes (%)	Cold No (%)	Consequences of the problems
Perceived problems due to heat					
Problems with drinking water	70.7	29.3			Health and hygiene
Can't cultivate the crops in due time	75.8	4.7			Production loss
Growths of crops has decreased	78.2	2.2			Production loss
yield of crops has decreased	77.1	3.1			Production loss
Can't go outside of house due to extreme heat	87.3	9.3			working hour loss
Have to work hard for irrigation	80.8	1.1			Extra work
Diseases/health problems/sickness has increased	96.2	3.1			Health problem
Perceived problems due to heat					
Boro (summer paddy) can't be cultivated timely			68.9	3.1	Food shortage
Boro (summer paddy) seedbed can't be shown			70.9	0.9	Production loss, food shortage
Potato cultivation is hampered			16.2	49.3	Food production loss
Betel leaf field is hampered			63.6	1.6	Cash crop loss
Robi (winter crops) crops can't be cultivated			47.1	26.2	Cash crop loss
Potato cultivation is hampered because of dense fog			60.7	2.7	Cash crop loss
Flowering /blooming is delayed			47.1	16.5	Cash & food loss
Color of the crops has faded			45.1	17.5	Cash loss
Mango inflorescence is hampered due to heavy fog			46.0	16.8	Cash & food loss

Source: Haque et al. (2012)

Water and Sanitation

Water availability is mainly dependent on the climate change, and the surface water availability depends on the timing and volume of rainfall. Inadequate access to improved water and sanitation has long been recognized as the resultants of the current burden of disease, particularly for the high rates of infant mortality in deprived urban areas (Kovats and Akhtar 2008). Socio-economic status at household level, particularly for the urban poor, is the root cause for the lack of access to improved water. However, cities in both high- and low-income countries have experienced failures in supply due to extreme drought events. It is also known that access to water within cities is not equally distributed, and any reductions in supply are likely to have a greater impact on pro-poor populations.

Floodwaters in slums can mix with raw sewage and breed water-borne diseases, such as diarrhoea, typhoid and scabies. Water supplies also become contaminated during floods, as pipes in slum areas are likely to be damaged or to leak. In a number of urban areas where the few available tube wells were submerged by flood waters, people collected water from schools, mosques or other places where the water sources were not inundated. Some boiled water or used alum/tablet (accessed from non governmental organizations) for purifying water. Some in the *Katasoor Beribadh* area of Dhaka city stated that they had to buy water ".... we also buy water from the owner of the deep tubewell....sometimes depending on the person it costs us Tk 10, 20 or 30." The women had to go on boat across to the main road to access water, ".... we have to walk to where the supply line is and then stand for a long time, and then we get our water. But it is free." Not everyone, however, could afford to buy water or wait in long queues, and basically resorted to drinking whatever dirty water was available. The common declaration was, "What to do, Apa?"

Many of the families swam to the nearest tube-well or available water source to access water for the households. One woman said, "Everyday my youngest daughter swam to the tubewell with a dekchi (cooking pot) and waited in the chest-deep water for a long time. After a great struggle she managed to collect one dekchi of water which I used for the whole day." This one pot of water was a precious asset for them and they had to use it very carefully for all their activities—cooking, washing and drinking.

Sanitation posed a serious problem, especially for women and young female adolescents. As men were generally more mobile, they went by rafts or boats to a distant area for defecation. The men also used trees and even rafts for this purpose. However, for women the situation was much more difficult and they spoke of shame and insecurity. Many of the women waited till dusk to defecate "…we go to attend nature's call early in the morning or very late in the evening…this is 'shorom' (shameful) for us…you are a woman, you know what it is like." Some used to defecate inside the house in polythene bags and others used to defecate deep in the floodwater while bathing. Sometimes, they could not find bushes to defecate because these were inundated. Poor urban women voiced their shame and embarrassment and often said, "what to do now…we put our thing (feces) in polythene packets or kagoj (paper) and throw it into the water....we don't have a choice but we feel very badly about this…." A few girls explained that they were so embarrassed to go to the toilet in public that they would wait till late at night when no one could see. One young girl explained her situation, "I just held it in- I would try not to go unless I really had to! What I would do is not eat at all sometimes or eat less so that I would not have to go to the toilet at all… then when I just couldn't anymore, I would and stand in the jol (water) and do it there. So much shame this is - To be out there in the open like this and do this - I felt so bad about it!"

In the less flooded slums, some of the residents devised a system of "hanging latrines"—precarious bamboo platforms raised a few feet above the ground, or water, and screened with rags with sewage and filth building around the vicinity. It was observed that the sanitation in public shelters were filthy as children defecated everywhere. Infants crawled and played in the faeces and dirt, mostly unattended, risking their health. Although the authority at the shelter got some bleaching powder to clean the latrines, the limited stock meant that the conditions were extremely unhygienic.

In some of the urban areas makeshift latrines were made on water bodies with bamboo poles and old clothes, especially for women. A few mentioned the indignity they faced as they were forced to take baths in front of the *para* (neighborhood) men and outsiders "…all of us bathe together, we take turn for having a bath by the side of the road… 'kee ar korbo' (what else to do)." Women also spoke of drinking less water and eating less food so that they would urinate and defecate less frequently. In desperation, one marooned woman in the urban slum lamented "…we cannot eat properly, we cannot bathe properly and we cannot leave the house to (use toilet)… what to do?"

Health Hazard Risk

Impacts of climate change on human health is newly emerged as the greatest concern which is happened due to changes in freshwater resources, food supplies and increases in extreme weather events such as floods and droughts (Table 4.4: Kovats and Akhtar 2008).

During the floods, it was observed that the water often rose above the tops of the stilts supporting some homes, flooding the floors and tiny alleyways with dead vermin, human faeces and other refuse. Disease was especially rife during this time. Fevers, diarrhoea, dysentery, scabies and tuberculosis often combine with malnourishment to impact on the weakest and most vulnerable among the very young and elderly. In the flooded slum areas visited, people were found to be increasingly suffering from respiratory infections, skin diseases and diarrhoea. Fungal infection on the skin of the legs due to prolonged submersion in dirty water was commonly observed. In addition to this, most of the respondents complained about developing sores on their feet and various skin diseases from walking in the filthy water.

People in the interviews complained of fevers and high temperatures. "Apa, my mother-in-law is so sick, because of all this dirty water." Another woman said, "My son is very sick, for the last few days he has dysentery and is very sick…" One two-month old child already died of diarrhoea in a public shelter (where families were taking refuge from the floods), while many children and adults were reported to be suffering from various illnesses (Karim et al. 1999). Most of the families struggling with loss of homes, dirty flood waters and lack of sanitation, had very little money or opportunity of seeking treatment for their ailments. Some of the slum women admitted quietly to taking their sick children to the local "huzur" (religious leader) or a "fakirani" (female faith healer). A woman complained of the lack of support services available for her children and her family, "…my son is so sick from 'amasha' (dysentery)…but there is no one around…where do we go?" Slum residents complained that few community health workers, if at all, either from government or NGOs came to visit and give medicine. Usually slum residents took treatment from nearby pharmacies or from general practitioners. But all the pharmacies were under water and the chambers of the private practitioners were also closed. The situation was worse for pregnant women; and two had already given birth (at the time of

Table 4.4 Summary of known effect of weather and climate on health

Health outcome	Known effects of weather
Heat stress	• Deaths from cardio-respiratory diseases increase with high and low temperatures • Heat-related illness and death due to heat waves
Air pollution-related mortality and morbidity	• Weather affects air pollutant concentrations • Weather affects distribution, seasonality and production of aeroallergens
Health impacts of weather disasters	• Floods, landslides and windstorms cause direct effects (deaths and injuries) and indirect effects (infectious diseases, loss of food supplies, long-term psychological morbidity)
Mosquito-borne diseases, tick-borne diseases (e.g. malaria, dengue)	• Higher temperatures reduce the development time of pathogens in vectors and increase potential transmission to humans • Vector species require specific climate conditions (temperature, humidity) to be sufficiently abundant to maintain transmission
Water-/food-borne diseases	• Survival of important bacterial pathogens is related to temperature • Extreme rainfall can affect the transport of disease organisms into the water supply. Outbreaks of water-borne diseases have been associated with contamination caused by heavy rainfall and flooding, associated with inadequate sanitation. • Increases in drought conditions may affect water availability and water quality (chemical and microbiological load) due to extreme low flows.

survey) and moved to their relative's homes. Another two women were living at a shelter and were on the verge of delivering but there were no facilities to assist the pregnant women in case of emergencies. The pregnant women were in a difficult situation in the shelter with restricted mobility, little privacy, and living in extremely congested and unhygienic conditions. Many families spoke of the helplessness of waiting desperately for support and the uncertainty of their situation.

4.4 Shelter and Insecurity

People in urban slums hung on to their own homes as long as possible until the water level compelled them to abandon their belongings. In urban slums, it was found that when water started pouring in, some families built bamboo platforms and shifted their belongings on it. In some cases, families raised their beds by putting bricks under it to raise the level of the beds. In some cases, families shifted to the roofs of their homes, if the roofs were sturdier. When everything was inundated, families reluctantly took shelter in nearby schools, or empty under-construction buildings (in urban area) or on nearby embankments or culverts. Where these were not available, they moved to take shelter by the side of the highways in makeshift shelters made with plastic sheets on bamboo frames. A woman said, "…my house is submerged, we sleep on the pucca rasta (main road)…what to do if there is nowhere else to go…?" The most devastating loss for the poor was the irreparable damage done to their homes. For the urban poor, security is having a roof over their heads. The women and men repeatedly cried over the loss of their homes. A group of men remarked "we have lost everything. Without our homes we have nothing and now our houses are gone, broken and destroyed...." Their sense of despair and utter helplessness at their present situation was overwhelming.

An important concern was the high incidence of theft occurring when families left their belongings and sought temporary shelter elsewhere. A woman narrated, "when we went for shelter, our fans and other items such as clothing and utensils were all stolen. Pieces of our tin roof was taken." One woman exclaimed, "Apa, what are we going to do, sort out our utensils and belongings or buy food? All we have is our home and now we have nothing, no tin, no home, everything is flooded!" Some remained awake in the night to guard against thieves. One man said, "I remained awake almost every night. There was darkness all around as there was no electricity. We used to hear rumors about looting in different parts of the city. I therefore kept watch on all the directions throughout the night. I only slept when I could not stay awake anymore." (Zaman 1999).

Several flood studies documenting people displaced by the floods found that slum dwellers do not re-locate too far from their original residing place. They prefer to remain nearby, in the hope that the area will remain undamaged. Many families also worried about theft and loss of hard earned goods in their homes, such as tins or electrical goods such as fans and utensils (Rashid 1999). As one man said, "when we went to relief camp our fans and other household items such as clothing and utensils were all stolen…you see that woman – pieces of her tin roof was taken away." A woman sadly said, "I stay awake all night to guard our household materials now that our house is under water; the children sleep next to me (on a polythene old torn sheet on the roadside) and I try to get some sleep but it is difficult to sit and watch and also sleep but these are my only belongings."

Sexual harassment and lack of privacy were important concerns for young women and their families who had moved to public shelters for refuge during the floods. In a number of interviews, families reported the harassment of their daughters and women by thugs and local goons in the shelters but were unable to do much as many of them had become separated from their networks of support and had little control over their new surroundings. One flood shelter in a school of Dhaka city near Sobhanbagh area had young women and their families from the neighboring slums seeking shelter and protection from the floods. There were reports of some "outsiders" who in collision with some miscreants from within the shelter attempted to sexually harass young women. Due to limited space, the slum dwellers irrespective of gender and age had to sleep near one another, leaving young girls and single young women (without male guardians) vulnerable especially after dark. Many parents and guardians shared their anxieties, "Our daughters or daughters-in-law stay awake in fear of harassment. We cannot sleep either."

Women and young girls spoke of having their modesty compromised as they had to use common latrine facilities, bathe and sleep in full view of male strangers. For the girls living in shelters, the particular concerns were to live with strangers, especially men and to be at risk of exposing parts of their body. A young girl living in a relief camp shared her distress regarding her new living arrangements: “Can you imagine the lajja (shame) for us girls? We had to stay in this in room and have to change our clothes, eat, sleep and do everything there for more than two months! When I was sleeping I would think to myself - how am I sleeping?” For young girls who were menstruating, the lack of privacy made it difficult for them to wash their cloth and dry it. Two younger women mentioned the problems with washing their menstrual cloths, “where will we wash it and dry it…there is no space to dry the cloths or to wash in clean water…” A young woman explained, “I didn’t feel good having it [periods] during this time because I felt lajja (shame) in front of all these men. It is already difficult to wash and because there is dirty water everywhere one cannot even bathe properly and the cloth does not even dry quickly. The blood is dirty blood and I just felt very unclean and dirty all the time!” The feeling of dirtiness was also expressed by some other girls. In addition to not being able to bathe properly, some of the girls explained that they had difficulty finding space and time to wash their menstrual rag without being seen by others. Due to the floods, there was limited space and most people were confined to cramped surroundings.

4.5 No Income and Asset Loss

During any disaster situation, work and wages become scarcer for the urban poor. Even though, a various types of incurred asset losses were also happened due to the flood of 1998 in the rural areas as well as urban areas (Table 4.5). The opportunities for alternative income were very limited during the floods of 1998. The prices of basic food items had multiplied, with severe stress imposed on the poor who were dependent on daily wages for survival. Many of the women shared, “Apa, now a mishti kumra (pumpkin) costs 12 taka or more, and 20 taka in some places. Before we could buy mishti kumra for 4 or 5 taka…now how can we buy and how can we sell?” Most of the urban poor are unskilled, and involved in the informal sector. A majority tend to work in uncertain jobs as wage laborers and daily laborers. Thus, during the flood such jobs are most likely to be affected and threatened.

All of the women and men complained of the lack of available work, “My husband cannot ride a rickshaw, it costs 30 taka daily to rent but where will he go with it…there is floods everywhere…so there is no income for us.” Another woman said, “My husband has been sleeping for two days, he has no work because now he makes only 20 taka a day riding a baby taxi.” A slum resident commented, “Well my mateer kaj (earth cutting) is completely finished. There is no work for me anymore.” Another man said, “I used to drive the truck from here to collect sand and/or bricks and take it to Gulshan and Baridhara. I earned 150 to 200 taka a day…now I have no job and I am unemployed.”

A mother and daughter, both of whom would break bricks for a living, were unable to do any work. The daughter said, “We usually go and work in Sobhanbagh but now it is all flooded and we cannot earn any money.” Another woman, who was

Table 4.5 Distribution of households reported to have incurred asset losses due to floods of 1998

	% of households incurred loss	
	Rural (n = 3,505)	Urban (n = 628)
Homestead	87	45
Furniture[a]	44	71
Utensils[a]	30	43
Poultry[a]	58	31
Livestock (cow/goat)	11	2
Fish (from inundation of ponds)	9	–
Trees (nurseries and small trees)	36	–
Suruchi (restaurant)	3.1	–
Supannya (grocery)	3.0	–
Baby Taxi/Tempo	–	1
Rickshaw/Rickshaw van	–	10
Shop	–	9
Small trade (mobile)	–	25

[a]From a smaller sample of 1,226 BRAC respondents in rural area and 178 BRAC respondents from urban area (Ahmed and Ahmed 1999)

still able to break bricks [although her place was slowly getting flooded], said that she was relying on the three takas she made per *tukri* (basket) to survive. A few women claimed that since their houses were completely submerged by the floodwater, the rent in the nearby bastis had risen, "Apa what will we do, pay rent of Tk 900 or try and eat food to live?" Others stated, "We cannot pay 200 taka rent and also eat, and with no income what are we going to do?"

Some women complained that they were unable to continue their income earning activities such as selling vegetables, sugarcane, and clothes because prices had risen and they were unable to buy or to sell. A woman who was repaying an NGO loan stated, "We cannot even sell sarees anymore, where is the money to repay?" Most women complained that they were having difficulties repaying loans owed, and resorted to borrowing from different people (loan sharks and relatives) to repay these loans. Thus, the consequence was further debt problems for the women and their families. It has been argued that the loss of one set of resources for the poor seriously affects the functioning of others, and disasters can send such families or particular members into a downward spiral, "intensifying their burdens and decreasing the prospect of recovery" (Wood 1998).

Men and women also spoke of cutting down food intake and worrying about their next meals. In some household visits, families shared that they had gone without food for a day and were managing on basic bread (*chappatis*) as they had limited income and options during this difficult period.

4.6 Adaptation Practices

Adaptation to climate change requires local knowledge, local competence and local capacity within local governments. It needs households and community organizations with the knowledge and capacity to act (Satterthwaite et al. 2007). Local governments have the also willingness to work with lower-income groups, particularly who are living at urban slums settings. In the next few decades it will not be a problem at all for most developed and well-organized cities with good-governance system, the adaptation method like structural adjustments practices would possibly be an effective alternative way (or good disaster preparedness) of protecting the risks from climate change. One example for structural adjustments practices was portrayed in a study after the Mumbai floods in 2005 (Chatterjee 2007). The poor household resort to elevating a board to secure some of the important and expensive items of the household (Fig. 4.4). Widening and covering of drains were also applied in some neighborhoods where local groups collectively cleaned, widened and covered drains in the settlement before monsoons.

Fig. 4.4 Structural adjustments by slum dwellers during Mumbai floods 2005, India (photo credit: Monalisa Chatterjee in 2007 during data collection period)

Currently, there is a large deficiency in regarding to address the successful adaptation technique or adaptation capacity to avoid serious or potential catastrophic impacts in the world. In most of the cases the local government is unwilling to ensure provision for infrastructure and for disaster risk reduction and disaster preparedness, even though they are used to refuse to work with the inhabitants who have the illegal settlements. For this reason a large section of urban population turns into the vulnerable condition to any increases of the intensity of natural storms, floods or heat waves, and to increased risk of a disease, constraints on water supplies or increases in food prices. These environmental disasters could be easily solvable for those cities – which have wealthier with better-governed systems (Satterthwaite et al. 2007).

Most national governments and international agencies have had little success in supporting successful local development in urban centres. They need to learn how to be far more effective in this and in supporting good local governance if they are to succeed in building adaptive capacity. In Bangladesh short courses on climate change and health for public health professionals are offered by several Public Health Institutions including James P Grant School of Public Health, BRAC University, Independent University of Bangladesh, North South University.

There are clear and obvious linkages between adaptation to climate change and most other areas of development and environmental management. However, currently no data base on existing activities on climate change is present in Bangladesh. An inventory check list of the climate change and related activities such as courses, research, interventions should be developed. Based on that information a network should be developed that could be engaged in prioritizing and facilitating relevant tasks.

4.7 Conclusions

These calamities, which greatly affected urban slum areas, provide a wealth of information and experience from which lessons can be culled to improve how we respond to future disasters. Slum populations may suffer disproportionately during a disaster as they remain generally marginalized and socially and economically excluded from basic services and support from the State. The situation from urban poor is dismal due to the overcrowding and lack of access to basic services, such as water and sanitation. Consequences of these living conditions include stress due to crowding, insecurity due to lack of housing and land tenure. These conditions worsen during floods and disasters. Slum populations require specialized medical attention during the relief phase, and could have specific concerns during the recovery phase, e.g. their ability to access appropriate health care services, etc. Experts generally agree that apart from taking active steps to reduce the possibility of global climate change itself, cities can take steps to prevent the harmful aspects of natural disasters by improving planning, putting in effective infrastructure adjustments, support networks after the events, long term recovery and networks of loss redistribution, and establishing all relevant steps for disaster preparedness. While, technical solutions are possible, but these solutions must also take into consideration unresolved development and structural inequalities, such as the city's growing slum population, which has doubled in the last decade, and which shows no signs of abating.

In supporting the millennium development goals governments globally have recognized the importance of addressing the rights of people who live in slum settlements. However in Bangladesh and in many countries around the world, while the people who live in slum settlements are an integral part of the city, their right to live safely in the city is not recognized or protected.

The absence of clear and forward-looking policies on urbanization and urban slum settlements discourages long term thinking and interventions to improve the long-term prospects of people who live in slum settlements. Dhaka is the world's fastest growing mega city; Bangladesh is predicted to be a megalopolis in three to four decades. In time this rapid increase in population density will be exacerbated by global warming. A sea level rise of 1.5 m will submerge 15 % of the country's landmass, further contributing to Bangladesh's exceptional population density and to the challenges associated with ensuring that the basic rights of the population are met. This future scenario emphasizes the urgency of developing strategies now to facilitate the management of the extreme population density that is predicted to characterize Bangladesh in 50–100 years.

References

Ahmed SM, Ahmed HS (eds) (1999) Experiences of deluge: the flood 1998. RED, BRAC, Dhaka

Ali A (1999) Climate change impacts and adaptation assessment in Bangladesh. Climate Res 12:109–116. http://research.fit.edu/sealevelriselibrary/documents/doc_mgr/412/Bangladesh_CC_Impacts_%26_Adaptation_-_Ali_1999.pdf

Chatterjee M (2007) Slum dwellers response to flooding events in the megacities of India. Mitig Adapt Strateg Glob Change 15:337–353

Friel S, Marmot M, McMichael AJ, Kjellstrom T, Vågerö D (2008) Global health equity and climate stabilisation: a common agenda, vol. 372 (November 8). www.thelancet.com

Germanwatch (2008) International NGO Germanwatch prepared the index of 170 countries styled Global Climate Risk Index 2009 (Daily Star, Dhaka Friday, December 5, 2008, page 16 – Pinaki Roy, from Poznan, Poland). The index was developed taking into account the indicators of total number of deaths, deaths per 100,000 inhabitants, absolute losses in million purchasing power parities, and losses per unit gross domestic production (GDP)

Haque et al (2012) Environ Health 11:1. http://www.ehjournal.net/content/11/1/1

Hogstedt C, Wegman DH, Kjellstrom T (2007) The consequences of economic globalization on working conditions, labour relations and workers' health. In: Kawachi I, Wamala S (eds) Globalization and public health. New York, Oxford University Press, pp 138–157

Hossain (2006) Rapid mass urbanization and its social consequences in Bangladesh: the case of the megacity of Dhaka. Presented at the 16th Biennial Conference of the Asian Studies Association of Australia, Wollongong, 26–29 June 2006

IPCC (2007) Climate change: the physical science basis. Working Group I Report, Intergovernmental Panel on Climate Change

Islam N, Angeles G, Mahbub A, Lance P, Nazem NI (2006) Slums of urban Bangladesh: mapping and census 2005. Dhaka, Centre for Urban Studies, 54 p
Karim F, Sultana S, Chowdhury AMR (1999) A visit to a flood shelter in Dhaka city. In: Ahmed SM, Ahmed HS (eds) Experiences of deluge: flood 1998. Monograph Series No. 15. BRAC, Dhaka, pp 40–45 (November)
Kjellstrom T (2000) Climate change, heat exposure and labour productivity. Proceedings of the 12 th Conference of the International Society for Environmental Epidemiology, Buffalo, USA, International Society for Environmental Epidemiology
Kovats S, Akhtar R (2008) Climate, climate change and human health in Asian cities. Environ Urban 20:165
Kreimer A, Arnold M, Carlin A (eds) (2003) Building safer. Cities: the future of disaster risk. Disaster Risk Management Series No. 3. The World Bank, p 103 (Tables 8.1), Washington DC
Mallick (2008) Growing environmental and climate growing environmental and climate refugees in Bangladesh: urgent refugees in Bangladesh: urgent actions are required. In: C40 Tokyo conference on climate change – adaptation measures for sustainable low carbon cities, 22–24 October 2008, by Dwijen L Mallick, Research Fellow Bangladesh Centre for Advanced Studies (BCAS)
Megacities (1995) Reducing vulnerability to natural disasters. ODA Overseas Development Administration. The Institution of Civil Engineers, Thomas Telford Publications
NIPORT, MEASURE Evaluation, ICDDR, B, and ACPR (2008) 2006 Bangladesh urban health survey. NIPORT, MEASURE Evaluation, ICDDR,B, and ACPR, Dhaka/Chapel Hill
Oxfam (2007) Adapting to climate change. What's needed in poor countries and who should pay? Oxfam briefing paper 104. Oxford
Rashid SF (1999) The poor in Dhaka city: their struggles and coping strategies during flood. In: Ahmed SM, Ahmed HS (eds) Experiences of deluge: flood 1998. Monograph Series No. 15. BRAC, Dhaka, pp 30–38 (November)
Rashid SF (2000) Female adolescents and their sexuality: notions of honour, shame, purity and pollution during the floods. Disasters 24(1):54–70
Rashid SF (2005) Worried Lives, Poverty and Reproductive Lives of Married Adolescent Women Living in Urban Slums in Dhaka City, Bangladesh. Doctoral Dissertation, The Australian National University, Canberra, Australia
Rashid SF (2009) Strategies to Reduce Exclusion among Populations Living in Urban Slum Settlements in Bangladesh. J Health Popul Nutr 27(4):574–586
Satterthwaite et al (2007) Adapting to climate change in urban areas: the possibilities and constraints in low- and middle-income nations. Human Settlements Discussion Paper. In: Satterthwaite D, Huq S, Pelling M, Reid H, Lankao-Romero P (eds) Climate change and cities, vol I. IIED, London. October 2007 (PDF): www.iied.org/pubs/display.php?o=10549IIED
Schlein, Kruger (2006) Urban poor worse off than rural poor but good policies can reduce slums. UN Habitat. http://www.citymayors.com/society/urban_poor.html. Accessed 15 Aug 2007
Streatfield, Karar (2008) Population challenges for Bangladesh in the coming decades. J Health Popul Nutr 26(3):261–272
United Nations Department of Economic and Social Affairs/Population Division (2007) World urbanization prospects: the 2007 revision. Executive summary. United Nations, New York
UN Habitat (2009) http://www.unhabitat.org/downloads/docs/presskitsowc2008/Dhaka%20extreme.pdf. Accessed 1 Jan 2009
Vlahov D, Freudenberg N, Proietti F, Ompad D, Quinn A, Nandi V, Galea S (2007) Urban as a determinant of health. Journal of Urban Health: Bulletin of the New York Academy of Medicine 84(3):16–26
Wood GD (1998) Security and graduation: working for a living in Dhaka's slums. Discourse 2(1):26–30
World Bank (2006) Clean Energy and Development: Towards an Investment Framework, Annex K, Washington, DC, World Bank
World Watch Institute (2007) State of the world 2007: our urban future. World Watch Institute, Washington, DC (2012). http://www.worldwatch.org/node/4752

Chapter 5
Integration of Climate Change Adaptation, Disaster Risk Reduction and Social Protection in Bangladesh: Contemporary Views and Experiences

Aminul Islam and Abu Sumon

Abstract This chapter is intended to enhance understanding of policy makers and practitioners on how DRR–CCA integration can be used for better risk management and social protections that empower the poor to build resilient communities and livelihoods. It is recognized that DRR and CCA from the perspective of Bangladesh case has tremendous commonalities between the two approaches. This chapter attempts to analyze that there are more advantages in the harmonized approach particularly from the perspectives of the beneficiaries, local administration and practitioners. There are, however, factors that hinder the application of such harmonized approach are (a) conceptual/paradigmatic; (b) policy issues; (c) source, channel, and mechanisms of funds; (d) institutional/jurisdictional; (e) political and power issue; (f) mechanism/procedural. This chapter begins with a global discussion on the integration issue and the lessons learnt are focused on remaining sections to the prospect of DRR and CCA integration in Bangladesh for its importance in enhancing resilience and sustainability as well that worth advocating. The key convergence of DRR–CCA needs to be defined in different scenario of climate induced disasters in terms of time, intensity and level of exposures. Bangladesh experience of rapid onset, slow onset and recurrent disaster prone regions needs case specific treatment while adopting policy, planning and budgeting process from the perspective of integration of DRR–CCA. This Chapter recommends for (a) creating an enabling environment for cross-sectoral integration and implementation, (b) improving integrated decision making and bridging the gap between scientific knowledge and the local needs; (c) planning, implementing and evaluating in the context of uncertainty and (d) improving adaptation technology, targeting and

A. Islam (✉)
United Nations Development Programme, Dhaka, Bangladesh
e-mail: aminul.islam@undp.org

A. Sumon
Community Based Adaptation Programme, UNDP-GEF, Dhaka, Bangladesh
e-mail: abu.sumon@gmail.com

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*, Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_5, © Springer Japan 2013

delivery. In conclusion what we are trying to achieve out of convergence issues is the paradigm shift from reactive to prevention of risks.

Keywords Climate adaptation • Disaster risk reduction • Resilience • Social protection

5.1 Introduction

Bangladesh is one of the world's most vulnerable countries to hydro-meteorological hazards and to the impacts of climate change. In the development landscape, there are emerging parallel tracks of paradigms of disaster risk reduction and climate change adaptation yet most of the subject matter, actors, geographical coverage and, indeed, the very partners and beneficiaries, are the same. With so much overlap, such a conceptual separation only serves to heighten the risk of fragmentation and of inefficient use of scarce resources.

According to the IPCC 4th Assessment Report, rainfall is predicted to be increased in the Himalayan catchment areas resulting in higher river flows in the monsoon seasons, causing large-scale flooding in Bangladesh. It is anticipated that 5–10 % increase in cyclone and associated tidal surge reaching up to 200 km inland in coming years will increase the vulnerability of coastal region.[1] Increased temperature has already started triggering slow desertification in the north and north-western (*Barind*) area, destroying ecosystem, depleting ground water and causing acute drinking water scarcity. Untimely heavy rain and repetitive flash floods destroy standing crops in the north-eastern region and is affecting livelihoods and food security, pushing thousands into poverty. Vulnerable communities at large in such hazard zone are struggling against chronic but increasingly severe trend of climate induced disasters needs social protection to overcome the development deficit.

The policy discourse on DRR–CCA integration and in some cases convergence are to address the common concern of either vulnerability reduction or enhancing resilience with due consideration on adaptive social protection issues in the face of emerging trend of climate change and disaster risk. This calls for identifying options for institutional arrangements and governance structures that brings climate and disaster stakeholders in a single platform to promote and practice convergence of DRR–CCA. This issue featured prominently in the 2007 Bali Plan of Action, which highlights DRR as a critical tool for CCA, opening up a range of possibilities for integration of CCA in DRR strategies. This policy initiative will contribute to create an enabling environment for bringing in multi-sectoral actors to work together in a single platform to ensure synergistic impacts of generating effective results with minimization of transaction costs.

Understanding the current context of community based DRR and CCA in the region is key to identifying how the two fields can work together more effectively.

[1] Inter-Governmental Panel on Climate Change, Fourth Assessment Report.

The conceptual and practical similarities and differences of DRR and CCA have been the subject of several recent studies (e.g., Thomalla et al. 2006; Mitchell and van Aalst 2008; Venton and La Trobe 2008; Mercer et al. 2010), which have found that whilst there are some political and physical distinctions between the scope of each field there is a key area of similarity—a focus on vulnerability reduction and the enhancement of resilience. Thomalla et al. (2006) argue that CCA and DRR projects need to adopt a common approach to reducing vulnerability, as the current disconnected ways of working have thus far failed to make significant headway towards vulnerability reduction.

A number of compelling arguments for the integration of DRR and CCA have been made (Glantz 2003; O'Brien et al. 2006; Lewis 2007) and discussions are occurring across scales to make this a reality. Key benefits of integration have been identified as: (a) reduced climate related losses through widespread DRR measures (b) increased efficiency of resources (financial, human and natural, which is crucial when considering aid efficiency) and (c) enhanced effectiveness and sustainability of CCA and DRR approaches (Venton and La Trobe 2008).

5.2 Disaster Risk Reduction

Disaster Risk Reduction (DRR) forms an essential component of effective disaster risk management (DRR + Disaster Management (DM)/preparedness, response, recovery). The concept of DRR stems from the Bangladesh tradition of cyclone preparedness and flood control as well as relief/development aid that has been operating in the country since before the 1970s. In the early 1990s, there was a paradigm shift away from reactive response to preparedness and risk reduction. This was the start of a comprehensive approach to disaster management that covered all hazards, all phases and all actors and was articulated internationally through the Hyogo Framework for Action, and nationally through the Comprehensive Disaster Management Programme (CDMP), Standing Orders on Disasters (SOD), National Disaster Management Plan and recently approved Disaster Management Act. Each of these national documents related to disaster management refers strongly about the climate change induced disasters and adaptation issues. While national policy documents on climate change such as Bangladesh Climate Change Strategy and Action Plan highlighted disaster management as one of the pillars.

The conceptual framework, institution, methodologies, and practices on the DRR–CCA integration appraised in the Local Consultative Group of development partners and government agencies for Disaster Emergency Response (LCG-DER)[2] exhibited a strong political buy-in, with the links with humanitarian coordination.

[2] Puji Pujion (2012). Presentation made in LCG Disaster Emergency Response meeting on DRR-CCA Linkages-Grassroots Perspectives in Bangladesh, based on findings of the UNDP-CDMP organized workshop held on 13 November 2012.

Practical experience from Bangladesh includes a strong funding related to social safety nets which is a potential area of DRR–CCA convergence for enhancing resilience and specific funding mechanism, such as the Local Disaster Risk Reduction Funding (LDRRF) under CDMP which takes care community based integrated intervention for vulnerability reduction.

5.3 Climate Change Adaptation

Climate change adaptation (CCA) is part of the larger climate change paradigm that consists of mitigation and adaptation. It mostly originates from the environmental sector and has broadened to encompass global warming and climactic variability. CCA relates primarily to dealing with the hydro-meteorological hazards; particularly the medium to long term uncertainties.

The framework for CCA is emerging and becoming increasingly organized through international instruments such as the Adaptation Funds and national strategies such as the National Adaptation Programme of Action and the Bangladesh Climate Change Strategy and Action Plan (BCCSAP 2009). CCA is also gaining increasing political support and attracting large scale financing regimes [MOEF, Bangladesh Climate Change Resilience Fund (BCCRF), and Bangladesh Climate Change Trust Fund (BCCTF)]. However, robust delivery mechanisms are yet to be established. Current experience shows that a significant part of these funding sources invested for disaster risk reduction programme such as building cyclone shelters, construction and reconstruction of coastal embankments and coastal afforestation for green defense.

5.4 Comparing DRR and CCA Grassroots Experience

There are a number of key commonalities and differences between DRR and CCA which affect their integration (Fig. 5.1). It is important to note that, at the local and grassroots and the highest level, there is no division and that this cleavage exists at the sectoral administrative/bureaucratic level.

DRR and CCA have the following differences:

- Content: DRR has the geological and urban hazards, CCA has climactic hazards;
- Range: DRR is immediate to medium term, CCA is medium to long term;
- Funding sources and channels;
- Institutional setup: DRR with MoDMR, CCA with MOEF.

DRR and CCA share the following commonalities:

- Hydro-meteorological hazards make up 80 % of the shared business;
- Share objectives, narratives, methods;

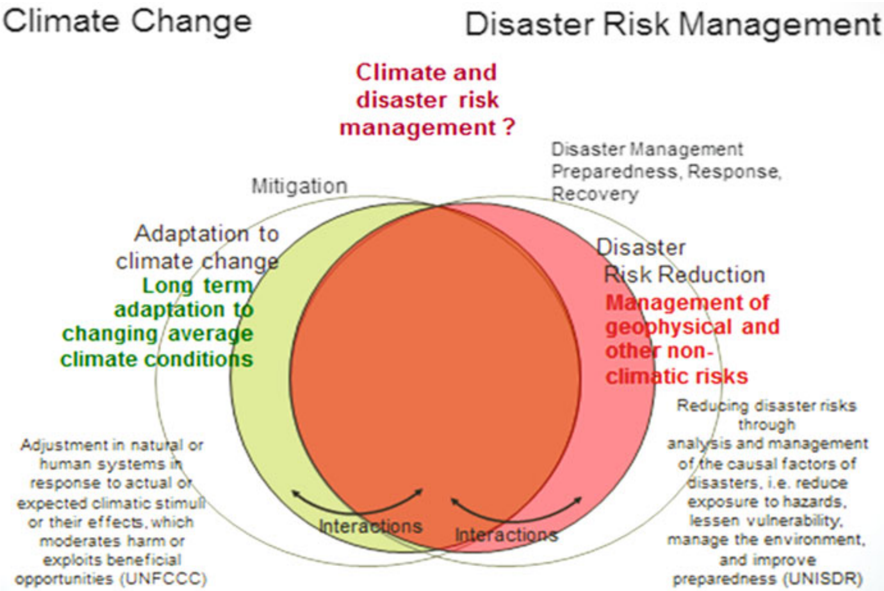


Fig. 5.1 Commonalities and differences between climate change adaptation and disaster risk reduction. [Puji Pujion (2012). Presentation made in LCG Disaster Emergency Response meeting on DRR–CCA Linkages-Grassroots Perspectives in Bangladesh, based on findings of the UNDP-CDMP organized workshop held on 13 November 2012.]

- High level policies are already cross referencing DRR and CCA;
- At local and grassroots level there is no difference;
- Involve the same delivery agents.

The workshop on “DRR–CCA Integration and Grassroots experience and perspectives” noted that the DRR and CCA divide stems historically from two separate conceptual constructs that each grow into separate disciplines.[3] There are however, scopes and foreseen advantages for integrated approach. As evidence from the field experience, at the grassroots level there is hardly any discernible division between the two approaches. This is also the case at the top level. The divide is tangible at the ministerial/sectoral levels, in part encouraged by the way development partners position their financing envelopes. In this regard, Bangladesh has been head and shoulder above other developing countries in practicing the DRR and CCA integrated approach. This workshop identified the following immediate actions for Bangladesh to take bold step in drawing a medium term development agenda with integrated DRR and CCA perspectives and urge the development partner’s concurrence and supports.

[3] UNDP Bangladesh and CDMP jointly organized workshop on “DRR-CCA Integration: Grassroots Perspective, held on 13 November 2012.

Advocacy

- Develop background/position paper and paragraph on country paper to share in global platforms on both climate and disaster themes.
- Document the good practices from the field level experiences.
- Develop strategy to engage the private sector.

Policy

- A joint session leading to an MOU between the parliamentary Standing Committees on the Ministry of Disaster Management and Relief and on the Ministry of Environment and Forestry.
- A policy advocacy to be presented to the said Parliamentary Joint Session
- Establishment of a national policy forum on the integration of the DRR and CCA

Planning and Financing

- Assist the Planning Commission to develop national budget with the DRR and CCA integration
- Develop a 5-year plan on the DRR and CCA with the integrated perspective
- Undertake joint advocacy to the development partners

Implementation

- Develop a handbook for local administration on the integration of DRR and CCA
- Develop a toolkits for Programme Officers/Practitioners on the integration of DRR and CCA

Alternative Options Towards Operationalizing DRR–CCA Integration

- It is imperative to push for the concept of either “resilience” or “vulnerability reduction” to encompass both disaster and effects of climate change/variability.
- Possibility of designing a new framework for “Climate and Disaster Risk Management”.
- Recognize and respect the distinct differences, push for harmonization rather than cooperation or total integration.

5.5 Linking CCA, DRR and Social Protection Towards Enhancing Resilience: A Few Issues and Practices

There is a growing concern that people living in vulnerable areas with poverty and deprivation cannot be protected solely by the promotion of economic growth. Specific interventions, targeting the most vulnerable sectors of the population, are increasingly considered as necessary complements to more traditional pro-growth policies, especially in the face of emerging climate change and unstable global socioeconomic scenarios as well. Social protection may be leveraged as one of the win–win policy options for development as it is an effective input for economic growth and it directly reduces poverty and disaster and climate change risks by targeting vulnerable households. Social protection, in this chapter has been framed as a policy response to risk, as a human right, and as an agenda for livelihood building. Nonetheless, social protection is generally described as the set of public and private mechanisms that protect and prevent individuals and households from suffering the worst consequences of shocks and stresses. Its novelty lies in its additional attempt to promote resilient livelihoods. However, almost any public intervention could be considered more or less directly part of the social protection system. In this perspective, education policy, pension systems, health care, and many other development policies will fall under a very vague definition of social protection. Such a definition would capture the complex system of linkages between social protection and all other social welfare components, but would hamper our understanding of the specificity of social protection in fighting climate induced disaster risk that erodes and limits livelihood opportunities and means of promoting economic growth. Brunori and O'Reilly (2010) reviewed and discussed the most influential definitions of social protection in the framework of development and aid policies and they explained how the operational definition of social protection has been conceived in the European Report on Development.[4]

5.5.1 Risk and Vulnerability in Agriculture and Rural Livelihoods

Livelihoods of poor rural people are characterized, threatened and affected by adverse shocks, and high levels of risk and vulnerability to those shocks and stresses. Weather-related shocks and stresses impact on agricultural production, affecting both small-scale producers and those working in larger-scale agriculture and non-agricultural enterprises in rural areas.

High reliance on subsistence agriculture means the impact of stresses and shocks (such as droughts or floods) are felt keenly by rural poor people who depend directly on agriculture for their survival. This has profound implications for livelihoods security and management, and therefore for growth and welfare. However, shocks will not necessarily lead to detrimental impacts. Embedded risk and uncertainty are intrinsic to agricultural practice, inherent seasonality contributes to this, and there is a considerable literature and experience on coping and risk management strategies.

[4] Brunori and O'Reilly (2010). Workshop paper on Social Protection for Development: a Review of Definition, Background paper to the European Report on Development 2010. Available in http://erd.eui.eu/publications/erd-2010-publications/background-papers/social-protection-for-development-a-review-of-definitions/.

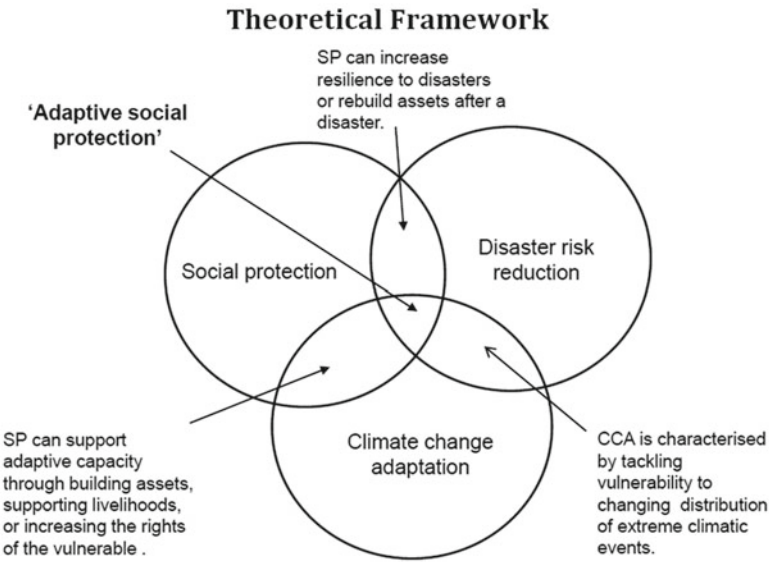


Fig. 5.2 Adaptive social protection

5.5.2 Social Protection in Agriculture and Rural Livelihoods

Social protection for the most vulnerable people has become a key policy response to risk and vulnerability in the agriculture sector. Agricultural policies can help people improve their livelihoods and security; the right social protection can complement these policies and help rural people not only to expand their assets, but to use them efficiently and adopt higher return activities that might otherwise be too risky. In essence, this approach enhances local people's "adaptive capacity", which will assist "autonomous adaptation" (Fig. 5.2).

5.5.3 Disaster Risk Reduction and Livelihoods

Disasters have a huge impact on livelihoods and on people's ability to cope with further stresses. Impacts such as loss of assets can lead to increased vulnerability of poor people to a "downward spiral of deepening poverty and increasing risk". Disaster risk reduction aims to make livelihoods more resilient to the impacts of disasters, hazards and shocks before the event.

In agriculture, disaster risk reduction programmes have been used to lessen the effects of persistent food shortages. Programmes include early warning systems, infrastructure investment, social protection measures, risk awareness and assessment, education and training, and environmental management. DRR has been shown to have a positive impact on agricultural and rural livelihoods.

5.5.4 Climate Change Adaptation: Links to DRR and Agriculture

Adaptation shares much in common with DRR in preventing harmful impacts of extreme events. It also brings additional challenges. While people have adopted practices to deal with changing weather and climate for centuries, including through disaster risk management, climate change leads to new risks that have not been experienced in recent history, including more severe drought impacts, heat-waves, cyclone intensity, and sea level rise. Future responses will need to be much more robust and, in some situations, new and innovative responses will be required.

Agriculture is already heavily engaged in adaptation efforts, through studies of water availability and crop yield, for example. More recent approaches build on people's ability to cope with existing variations in climate. This is often poverty-focused, addressing underlying structural causes of vulnerability that can entrench poverty, including poor access to resources, and lack of information and capacity. But global processes and crises are changing, deepening risks faced by poor, vulnerable people in rural areas. There are likely to be impacts on food production and distribution systems in many parts of the world with effects on purchasing power.

There is still uncertainty around the precise impact of climate change on agricultural/rural livelihoods. Even so, some studies suggest that the effects overall will be negative for developing countries: "The impact of climate change on food security will be higher in those countries with low economic growth potential that currently have high malnourishment levels" (FAO 2005:3). These impacts will interact directly with other issues such as changing pest and disease patterns, compounding problems already faced by poor rural people over the longer term.

There is not so much focus on the gradual changes of CC—reactive approach to large scale visible impacts—need to be proactive to the chronic changes of CC which can and will lead to disasters of another sort. The process we go through is not about inventing new tools or new pathways to development—it is about doing better within the context of climate change. Many existing frameworks for sustainable development and livelihoods and for disaster risk reduction are relevant tools which can be adapted to incorporate responses to known CC impacts. However, there is a real need to connect the scientific community to the local scale where these changes and coping mechanisms are taking place.

5.6 Suggested Institutional Arrangement Towards DRR–CCA Integration

Functional interaction and sequences for institutional arrangements and governance structures that may bring climate and disaster stakeholders in a single platform to promote and practice convergence of DRR–CCA towards achieving the

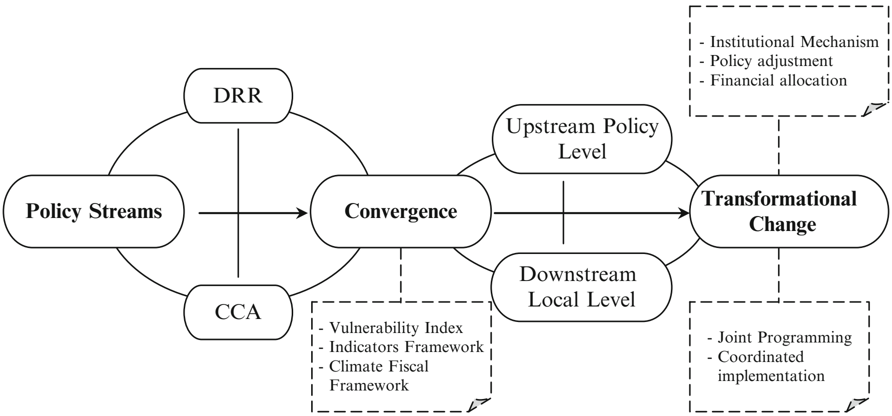


Fig. 5.3 DRR–CCA convergence towards transformational change. [M.A. Islam (2012). Unpublished policy concept on DRR–CCA integration drafted for UNDP, Bangladesh.]

transformational change is suggested in the following Fig. 5.3. This converging initiative may be guided by some information based decision making tools such GIS based multi-hazard trend, climate environment and disaster data based composite vulnerability index and available climate and disaster indicators, household survey based shocks and so on. Scientific data generation on climate and disaster impact on the vulnerable community will drive the decision making, programming and resource allocation process. This will create enabling environment for bringing stakeholders together in a single platform to ensure synergistic results with minimization of transaction costs.

Learning from the field experience reveals the fact that CCA and DRR projects need to adopt a common approach to reducing vulnerability, as the current disconnected ways of working have thus far failed to make significant headway towards vulnerability reduction. We have observed that whilst there are some political, ecosystems and physical distinctions between the scopes of each field but there is a key area of similarity with a focus on vulnerability reduction and the enhancement of resilience.

Climate system is fundamental for both issues (DRR as well as CC). In Bangladesh case more than 75 % of all disasters originate in weather–climate extreme. DRR and CCA strategies are both aimed at enhancing sustainability, resilient societies and human security and share similar sectoral focus, complexities and challenges, relying on same type of measures and policies (e.g. Water Policy, Coastal Zone Policy, and Five Year Plan etc.). DRR offers opportunities for “bottom-up” strategies for adaptation to current climate variability including climate extremes can promote early adaptation to climate change.

Table 5.1 Key characteristics of social protection, adaptation and DRR

	Social protection	Adaptation	DRR
Core disciplinary grounding	Development and welfare economics	Social development and physical sciences	Physical sciences and social development
Dominant focus	Implementation of measures to manage risk	Enabling processes of adaptation	Prevention of disaster events and preparedness to respond
Main shocks and stresses addressed	Multiple	Climate-related	All natural hazard-related, including climate and geophysical
International coordination	Informal, EU, DFID, OECD task group	UNFCCC—Nairobi Work Programme	UN-ISDR Hyogo Framework for Action
Main funding	Ad hoc multilateral and bilateral	Coordinated international funds: Global Environment Facility UNFCCC/Kyoto Protocol funds Ad hoc bilateral	Coordinated international funding: ISDR, GFDRR, UNDP, Red Cross, ad hoc civil sponsored and bilateral

5.6.1 Key Policy Issues

Experience in CCA–DRR linkage and social protection have much to contribute to adaptation policies for the poorest, most vulnerable communities. Conversely DRR and social protection need to assess the extent they can handle changes in frequency and intensity of extreme weather events. Table 5.1 highlights key features of these three policy areas, some overlapping.

5.6.2 Towards Transformative and Adaptive Approaches Through Social Protection

The social protection policy agenda focuses on the poorest sections of society, typically the bottom 10 % of the population, and the transfer of resources (especially cash) to households to smooth consumption or support income. In DRR, efforts within relief and recovery are designed to smooth the social impact of shocks, with far less emphasis on preventative approaches that tackle disasters from a holistic perspective. In adaptation, attention to building on existing coping practices is also focused on smoothing shocks as a first step.

Social protection has much to offer in helping the poorest reduce their exposure to current (DRR) and future (adaptation) climate shocks. Table 5.2 highlights potential adaptation benefits of different strands of social protection.

Table 5.2 Promoting adaptation through social protection

SP category	SP instruments	Adaptation and DRR benefits
Provision (coping strategies)	– Social service provision – Basic social transfers (food/cash) – Pension schemes	– Protection of those most vulnerable to climate risks, with low levels of adaptive capacity
Preventive (coping strategies)	– Safety nets – Social transfers – Public works programmes – Livelihood diversification – Weather-indexed crop insurance	– Prevents damaging coping strategies as a result of risks to weather-dependent livelihoods
Promotive (building adaptive capacity)	– Social transfers – Access to credit – Asset transfers/protection – Starter packs (drought/flood-resistant) – Access to common property resources	– Promotes resilience through livelihood diversification and security to withstand climate related shocks – Promotes opportunities arising from climate change
Transformative (building adaptive capacity)	– Promotion of minority rights – Anti-discrimination campaigns – Social funds	– Transforms social relations to combat discrimination underlying social and political vulnerability

5.6.3 Developing "Adaptive Social Protection": Future Perspective

This note illustrates the links between social protection, climate change adaptation and DRR in the context of rural development. There are examples how current experiences of social protection have much to offer to protecting the poor to current (DRR) and future (adaptation) weather extremes. Possible ways in which social protection programmes themselves can be made more robust in the face of current and future shocks:

- *Climate proofing social protection* through a long-term vision in the context of more reliable and accurate predictions and consideration of vulnerability.
- *Policy and programmatic options* for social protection for climate change adaptation.
- *A preventative and holistic poverty approach* for DRR.
- *An improved growth focus* for agriculture and rural development.

By placing social protection in the context of the impacts of natural phenomena, particularly climate, on agricultural productivity and related livelihoods, we may establish a framework for social protection measures that are resilient to disaster risks, and that acknowledge the changing nature of climate-related impacts including the future existence of conditions that have not been experienced before. This *adaptive social protection* should be characterized by a number of features that include:

- An emphasis on transforming productive livelihoods as well as protecting, and adapting to changing climate conditions rather than simply reinforcing coping mechanisms.
- Grounding in an understanding of the structural root causes of poverty in a particular region or sector, permitting more effective targeting of vulnerability to multiple shocks and stresses.
- Incorporation of rights-based rationale for action, stressing equity and justice dimensions of chronic poverty and climate change adaptation in addition to instrumentalist rationale based primarily on economic efficiency.
- An enhanced role for research from both the natural and social sciences to inform the development and targeting of social protection policies and measures in the context of the burden of both geophysical hazards and changing climate-related hazards.
- A longer term perspective for social protection policies that takes into account the changing nature of shocks and stresses.

This is not to assume that all DRR, adaptation and social protection work will, or indeed should, necessarily meet all of these characteristics. There are likely to still be roles for specific policies and instruments within each of the fields. However, this framework and analysis should permit the identification of a number of potential areas for future work that links these related fields together, and a number of ways to address the challenges of developing adaptive social protection in the broader context where agriculture and rural development is a part but not the only consideration.

5.7 Integration of DRR and CCA in the Context of Emerging Risks

The drive towards the convergence of the Disaster Risk Reduction (DRR) and the Climate Change Adaptation (CCA) has gone a long way. The climate change adaptation, in other words the management and coping with increased variability and extremes of climatic events, shares a great deal with disaster risk reduction. The changes in magnitude, intensity, frequency and spatial distribution of disasters in Bangladesh are evolving and accelerating over a long period. These patterns represent a long-term change in the climate that slowly changing the natural hazards from one-off events into far more common phenomena. Floods, droughts, cyclones and other hazards can no longer be dealt with as recurrent events in a sequence of disaster and recovery. Left unattended an increased flooding associated with the rising sea levels will, sooner or later, overwhelm millions of people in coastal communities, leading to significantly increased levels of internal displacement and migration.

The government of Bangladesh and its people has wealth of experiences in preparing for, and responding to, disaster events. In recent years, Bangladesh has been playing a leading role in adopting a more holistic approach to risk reduction. Ahead of the global shift in thinking on approaches to disasters, and most specifically with the strategic priorities of the Hyogo Framework for Action (HFA), the stated vision of the Government of Bangladesh (GoB) has shifted its focus from conventional disaster response to more comprehensive risk reduction approach.

The integration of disaster risk reduction (DRR) and climate change adaptation (CCA) within the national plan and programmes has been recommended in COP13, Bali 2007 as part of the UNFCCC negotiation process. National Plan for Disaster Management (NPDM 2010–2015) of GoB highlights that disaster risk reduction can promote early adaptation to climate risks and impacts and offers opportunities for “bottom-up” strategies for adaptation to current climate variability and climate extremes. Bangladesh’ National Adaptation Plan of Action (NAPA 2005), Bangladesh Climate Change Strategy and Action Plan (BCCSAP 2009) are prepared to tackle climate change impact in convergence with the disaster risk reduction.

5.8 Integrating CCA in DRR: Initiatives and Experiences of CDMP[5]

Realizing that the challenges and impact of climate change and disaster are development concern, CDMP was designed to have key elements that create synergies between disaster risk reduction and climate change adaptation.

5.8.1 CDMP Phase I (2004–2009)

CDMP built appropriate mechanism, create convergence of climate change and disaster risk reduction by translating hard science of climate change prediction into tangible, community-level actions to support adaptation. Concurrently, CDMP also initiated and facilitated the establishment of the government structure, mechanisms, and capacities for climate change adaptation. These include:

- Supported Department of Environment of the Ministry of Environment and Forest to establish the Climate Change Cell and successfully initiated adaptation

[5]Comprehensive Disaster Management Programme (CDMP), Phase I was implemented by the Ministry of Food and Disaster Management during 2004–2009 with support from UNDP, European Union and DFID.

research, built capacity for climate change prediction modelling, and established a climate change database.
- Supported the Livelihood Adaptation to Climate Change (LACC) project that integrated disaster risk reduction and climate change adaptation in agriculture and allied sectors through community level adaptation trial. The Project identified and validated 90 Climate Change Adaptation options of which 60 were tested in the farmers' field. Some of the widespread adaptation options are: Rain water harvesting in mini pond and supplemental irrigation improved the rice yield by 23 %, water saving irrigation practice increases the water use efficiency of rice by 20 %, improved stove (costs US$10/household) saves 30 % fuel use and reduces 35 % cooking time.
- During 2005–2009 the Local Disaster Risk Reduction Fund (LDRRF), established within CDMP supported more than 560 small, medium scale risk reduction and community based adaptation projects in more than 380 Unions in 11 districts benefiting over 600,000 vulnerable people.

Programmatic lessons learnt from CDMP Phase I include the followings:

1. The broadening of the perspectives to the all hazards perspectives and the integration with climate change is not only inevitable but a necessity.
2. Broader outreach of the DRR and CCA requires the involvement of all sectors.
3. The Programme provided sufficient momentum for mainstreaming into the development planning and the strategic scaling up of the pilot interventions to the wider geographical areas.
4. Mainstreaming of the DRR and CCA requires the leveraging to the regional platform.
5. Local acceptance of adaptation options is very much determined by the livelihood system and wealth status (including land ownership or otherwise) of the farming households.
6. Climate change adaptation appears to be *highly location specific, not every size fits all.*
7. Uptake of climate change adaptation measures is as much to do with *social learning process* as with issues related to technology transfer and capacity building.

5.8.2 CDMP Phase II (2010–2014)

Building upon the achievements and lessons of CDMP I, Phase II attempted to further integrating disaster risk reduction (DRR) and climate change adaptation (CCA) with support from UNDP, DFID, EU, Norway, SIDA and AusAid. It continues to work on mainstreaming of climate change and disaster risk reduction into national development planning process as well as generating appropriate knowledge and technologies for community based adaptation, bridging the gaps between climate science and the community; contingency planning for vulnerable populations living in very high-risk areas; and awareness raising and policy advocacy for adoption and scaling up. Objective of the CDMP II activities are:

- Convergence and institutionalization of DRR and CCA into development planning and programmes in all level through development of tools and frameworks, policy advocacy and awareness raising.
- Generate knowledge by translating scientific information for policy making and appropriate technological options.
- Implement sustainable livelihood options at regions vulnerable to climate variability along with documenting and dissemination of learning for scaling up.

5.8.3 Major Achievements and Plans of CDMP II

Institutional Reform

- CDMP is building collaborative partnership and facilitating 13 government's line department/ministries (list appended) for them to better understand and integrate climate change adaptation and disaster risk reduction needs in to their respective domains. CDMP is facilitating departments in integrating CC concerns and issues, mainstream them and more practical action in drawing departmental strategies, process and policies including action plan of DRR and CCA for their respective department/sector.
- In partnership with UNDP supported Poverty Environment Climate Mainstreaming (PECM) Project and jointly with various ministerial agencies and department, process is initiated to integrate DRR and CCA issues into the development planning process through revision of Development Project Proforma (DPP) format and sectoral policies.
- Outlines for a training module on climate change impact, prediction analysis and review of adaptation plans have been developed to train Ministry of Disaster Management (MoDM) and Department of Disaster Management professionals, Disaster Management Committee (DMC) members and Community Risk Assessment (CRA) implementing partners. National training institutes or organization will be engaged for the training programmes that includes Training for Trainers (ToT) with the newly developed content.
- DRR/CCA pilot project implementations by the local governments. CDMP facilitates the Upazila (sub-district) DMCs to undertake the DRR/CCA pilot projects as guided by the results of the CRA and Risk Reduction Action Plan (RRAP) with the technical supports from NGOs. This approach expects the local government to own the pilot projects and, eventually, incorporate the same into their respective local plan, programmes and budgets.

Knowledge Generation

- Filling the knowledge gap in climate change adaptation a large selection of need-based and demand driven research agenda have been identified, prioritized and validated through regional, sectoral and national consultation to understand the anticipated climate-induced risk and the planned adaptation for sustainable development. This will be used as inputs for conducting study and research by national research organizations and institutes.
- Producing Union Fact Sheet for almost half of the countries' unions where CDMP is expected to be working capturing demographic and socio-economic information, institutional settings, environmental features, local hazards profile etc. The Fact Sheet serves as a common reference for both the DRR and CCA.
- A study on climate resilient non-farm livelihood adaptation approaches and technologies is being carried out to identify options which will be translated for potential use and eventually promoted to the project beneficiaries.
- Partnering with Bangladesh University of Engineering and Technology (BUET), a study has been undertaken to analyse the past 50 years climatic parameters (Rainfall, Temperature, Sunshine, Humidity) for better understanding of climate regime and trend for the country.
- Initiating the studies on trend, impact and future scenarios of the most common hazards, e.g. flood, drought, storm surge and salinity intrusion to inform the devising of the adaptation plan.
- Partnering with Department of Agriculture Extension (DAE), community consultations were organized to share, identify, validate and compile the indigenous knowledge, options and technologies for climate change.
- An in-depth assessment and analysis of the potential impact and future trend of the internal displacement due to various climate induced disasters has been initiated to support strategic and contingency planning.

Community Based Adaptation

- A set of climate change impact and vulnerability screening tools, pulled in a package "Climate Lens", have been incorporated to the participatory and bottom up CRA and RRAPs process. Concurrently CDMP revised the rural risk reduction strategies to reconcile the broad geographical coverage, the impact effectiveness, and sustainability while, at all time, integrates the DRR and CCA.
- LDRRF fund has been using for implementing close to 750 small scale community level risk reduction projects mostly addressing the pressing lack of access to safe drinking water in 11 most vulnerable unions of 5 Super Cyclone *AILA* affected south western coastal districts including development of 2 climate resilient villages. Partnering with Housing and Building Research Institute (HBRI) for the designing, construction and installation of 200 "Cyclone Resistant Houses" in these two villages.

- Various initiatives are underway to expand the Local Disaster Risk Reduction Fund (LDRRF) interventions in 2,000 unions of 40 districts and establishing at least 7 climate resilient villages. Based on the learning and lessons from livelihood adaptation to climate change (LACC) projects, phase II initiated further piloting of climate change agricultural options. In the northwest, piloting of a drought tolerant rice variety *Nerica* yield new lessons and experiences.

Risk Reduction as Adaptation Measures

- CDMP continues to undertake the disaster risk reduction interventions to be formulated through processes that take on board climate change adaptation considerations. The continuing effort to address the salinity problem in the south-western region, for instance, is a prime example of addressing both concerns in one go.
- Taking bold initiatives through DRR and CCA unconventional interventions, CDMP once again proves its flexibility and capacity to deal with emerging risks. The Resilient Habitat pilot project has been launched in the south-western region to demonstrate solutions to the DRR and CCA issue through comprehensive approach.
- Putting importance to the demonstrative effects of the DRR and CCA pilot projects. CDMP is increasingly in favour of geographically clustered project with close proximity to heighten the demonstrative effects to the intended reduction of the disaster and climate change risks.

5.9 Concluding Remarks

For Bangladesh intensified and frequent natural disasters and climate variability are the key impact of climate change. Hence, reducing disaster risk is the most effective strategy for climate change adaptation. Climate change and disaster challenges can and should also be seen as opportunities for poverty reduction. Ecosystem based adaptation is the pre-cursor of sustainable risk reduction as well as livelihood endeavor needs attention. Investment in DRR and CCA reduces response cost should be the strategic approach in development planning. The challenges that climate change adaptation and disaster risk reduction is likely to present cannot be addressed ad hoc, or haphazardly, and require careful planning and meaningful coordination should be beginning now. The likely impacts of climate change are multi-sectoral and multi-faceted and require across-the-board integration into all kinds of national policy, planning and programming. Potential incentives in DRR–CCA convergence lies in the fact that it (a) contribute to poverty reduction and sustainable development; (b) reduce vulnerability to both sudden and slow onset hazards; (c) recognize food and socioeconomic insecurity as part of vulnerability; (d) more effective partnerships with non-government partners and (e) better use of structural and non-structural interventions.

References

Brunori P, O'Reilly M (2010) Social protection for development: a review of definitions

FAO (2005) Climate change water and food security. FAO Water Reports, Rome, p 3

Glantz MH (2003) Climate affairs. Island Press, Washington, DC

Islam MA (2012) Unpublished policy concept on DRR–CCA integration, UNDP, Bangladesh

Lewis J (2007) Climate and disaster reduction. Tiempo Climate Newswatch. Available at http://www.tiempocyberclimate.org/newswatch/comment070217.htm

Mercer J, Kelman I, Taranis L, Suchet-Pearson S (2010) Framework for integration indigenous and scientific knowledge for disaster risk reduction. Disasters 34(1):214–239

Mitchell T, van Aalst M (2008) Convergence of disaster risk reduction and climate change adaptation. A review for DFID. Institute of Development Studies, Brighton

O'Brien G, O'Keefe P, Rose J, Wisner B (2006) Climate change and disaster management. Disasters 30(1):64–80

Thomalla F, Downing T, Spanger-Springfield E, Han G, Rockstorm J (2006) Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation. Disasters 30(1):39–48

Venton P, La Trobe S (2008) Linking climate change adaptation and disaster risk reduction. Tearfund and the Institute of Development Studies, London

Part II
Strategy and Action Plan

Chapter 6
National Adaptation Programme of Action

Aminul Islam, Rajib Shaw, and Fuad Mallick

Abstract National Adaptation Programs of Action (NAPAs) provide a process for Least Developed Countries (LDCs) to identify priority activities that respond to their urgent and immediate needs to adapt to climate change—those for which further delay would increase vulnerability and/or costs at a later stage. The steps for the preparation of the NAPAs include synthesis of available information, participatory assessment of vulnerability to current climate variability and extreme events and of areas where risks would increase due to climate change, identification of key adaptation measures as well as criteria for prioritizing activities, and selection of a prioritized short list of activities. Bangladesh National Adaptation Programme of Action (NAPA) was prepared by Ministry of Environment and Forest, Government of the People's Republic of Bangladesh in partnership with relevant specialized Agencies and institutions as a response to the decision of the Seventh Session of the Conference of the Parties (CoP7) of the United Nations Framework Convention on Climate Change (UNFCCC). The updated NAPA 2009 is well aligned with the BCCSAP and would address the following thematic pillars in terms of identifying short and medium term adaptation measures: (a) ensuring food security and pro-poor social protection of the climate vulnerable people; (b) strengthen comprehensive disaster management programme; (c) climate resilient infrastructure development including sustainable cities; (d) mainstreaming climate change in local and national development; (e) capacity enhancement including research and knowledge management and institutional strengthening and (f) strategic natural resource management as an adaptation response to climate change including wise use of wetlands, rivers, flood plain system.

A. Islam
United Nations Development Programme, Dhaka, Bangladesh

R. Shaw (✉)
Graduate School of Global Environmental Studies, Kyoto University, Kyoto, Japan
e-mail: shaw.rajib.5u@kyoto-u.ac.jp

F. Mallick
BRAC University, Dhaka, Bangladesh

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*,
Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_6, © Springer Japan 2013

Keywords Capacity enhancement • Climate resilient infrastructure • Food security • Mainstreaming climate change • NAPA • Natural resource management.

6.1 Introduction

National Adaptation Programs of Action (NAPAs) provide a process for Least Developed Countries (LDCs) to identify priority activities that respond to their **urgent** and **immediate** needs to adapt to climate change—those for which further delay would increase vulnerability and/or costs at a later stage (UNFCCC 2009). The main content of NAPAs is a list of ranked priority adaptation activities and projects, as well as short profiles of each activity or project, designed to facilitate the development of proposals for implementation of the NAPA. To facilitate access to project details from the NAPAs, the UNFCCC secretariat has developed a NAPA Project Database. The NAPA project database webpage contains:

- Index of projects by country, including project costs
- Index of projects by sector, including project costs
- Lists of project profiles by sector, grouped according to the main sectors in which the project falls. Some projects and activities are very cross-sectoral in nature, and difficult to classify into any one sector. Such projects have been put into a "cross-sectoral" group
- Lists of projects by country showing cost with a downloadable pdf of project profiles per country

Focus of NAPAs: The NAPAs focus on urgent and immediate needs—those for which further delay could increase vulnerability or lead to increased costs at a later stage. NAPAs should use existing information; no new research is needed. They must be action-oriented and country-driven and be flexible and based on national circumstances. Finally, in order to effectively address urgent and immediate adaptation needs, NAPA documents should be presented in a simple format, easily understood both by policy-level decision-makers and by the public.

The NAPA process: The steps for the preparation of the NAPAs include synthesis of available information, participatory assessment of vulnerability to current climate variability and extreme events and of areas where risks would increase due to climate change, identification of key adaptation measures as well as criteria for prioritizing activities, and selection of a prioritized short list of activities. The development of a NAPA also includes short profiles of projects and/or activities intended to address urgent and immediate adaptation needs of LDC Parties.

This chapter is adapted summary of the NAPA 2005 and the updated version of 2009 prepared by the Ministry of Environment and Forest, Government of Bangladesh.

6.2 Key Climate Change and Environmental Stresses

There are several environmental issues and concerns to development that are already hindering development process of Bangladesh. Climate change will become an additional issue and concern as it will aggravate several of those problems in future. A brief description of key environmental stresses related to development and climate change are given below.

6.2.1 Land and Soil

The productive agricultural land is decreasing rapidly as it has been diverted to other uses, mainly for urbanization and building of human settlement. The annual loss of productive arable land stands at about 100 thousand ha. There are also structural changes that decreased medium and large farms while increased small and marginal farms.

In addition to structural change of land use, riverbank erosion is rampant in areas along the active river channels of the Ganges, the Jamuna and the Tista and in the coastal and offshore areas of Bangladesh. About 1.7 million hectares of floodplain areas are prone to riverbank erosion (Karim and Iqbal 2000). It has been observed that between 1973 and 1996, a total of 73,552 ha of land was eroded while only 10,628 ha of land have been formed by accretion (WARPO 2000). Physical, chemical and biological properties of soil are deteriorating including organic matter, loss of micro nutrient, increase soil salinity, lack of proper replenishment of plant nutrient and so on. Forty five per cent of net cultivable land area has even less than 1 % organic matter. Out of 2.85 million hectares of the coastal and offshore areas, about 1.2 million hectares of arable land are affected by varying degree of soil salinity. Tidal flooding during wet season, direct inundation by saline or brackish water, upward or lateral movement of salinity in groundwater during the dry season and inundation with brackish water for shrimp farming are key causes of salinization in coastal land. The severity of salinity problem has increased over time with the desiccation of the soil.

6.2.2 Water

Bangladesh is richly endowed with water resources. The water ecosystem comprises the tributaries and distributaries of the three major rivers system, the Ganges-Padma, the Brahmaputra, and the Meghna (GBM), and numerous perennial and seasonal wetlands known locally as *haors, baors, pukurs, dighies, khals* and *beels*. Owing to the fact that 92 % or more of Bangladesh's annual runoff enters into the country from outside its borders, there is a high degree of uncertainty about the quantum of the water that will be available from trans-boundary rivers in future due to climate change. In the monsoon, the combined flow of the Ganges and the Brahmaputra reaches a peak between 80,000 and 140,000 m^3/s. Dependable flow (80 %) in the Ganges (according to the Ganges Treaty) can be less then 1,000 m^3/s in dry season. Mainly two types of problems exist in the coastal water bodies, namely, salinity in the estuarine areas, and water pollution in the marine zone. The magnitude of these problems depends on seasonal freshwater flow from the rivers, and operation of seaports. Generally, water scarcity is a dry season phenomenon when the availability becomes less than the demand, or the quality of the water restricts its use. Dry season water resources are comprised of the runoff and trans-boundary river inflow, together with water contained in surface water bodies and groundwater. Scarcity is also dependent on the amount of soil moisture available at the beginning of the season. Trans-boundary inflow in the dry season has decreased due to upstream development, and withdrawal of water for irrigation and other purposes. Groundwater is the major source of irrigation in Bangladesh, and there has been a tremendous increase in suction mode irrigation.

6.2.3 Biodiversity

The terrestrial and aquatic areas of the country support a large number of diverse biological populations, both plant and animal. The biodiversity depends on the type and quality of habitat, and level of interference of the human population and development activities. Notwithstanding insufficient baseline information on biological resources, it is believed that development practices and population pressure have caused a significant depletion of terrestrial and aquatic species diversity. For example, 41 vertebrate species have been extinct from Bangladesh, and 106 species of globally threatened vertebrates identified. Mangrove forests form a unique environment of floral–faunal assemblages. Leaf litter undergoing decomposition provides particulate and dissolved organic matter to the estuarine ecosystem, and this complex detritus-based food web supports a number of marine and brackish water organisms. The Sundarbans support a very rich and diverse fish fauna of 400 species, 270 species of birds, and over 300 species of plants. It is an important staging and wintering area for migratory shore birds, gulls, and terns. They comprise the largest remaining tract of habitat for the Royal Bengal Tiger (*Panthera tigris*). St. Martin's Island is an important nesting area for marine turtles, and a wintering ground for migratory shore birds.

6.2.4 Disasters

The geographical setting of Bangladesh makes the country vulnerable to natural disasters. Every year one or more natural calamities upset people's lives in some part of the country. The major disasters concerned here are the occurrences of flood, cyclone and storm surge, flash flood, drought, tornado, earthquakes, riverbank erosion, and landslide. These extreme natural events are termed disasters when they adversely affect the whole environment, including human beings, their settlements, or the resources essential for their livelihoods.

6.3 Impacts of Climate Change and Variability on Biophysical and Key Sectors

Over the last decade a number of studies have been carried out on impacts, vulnerability and adaptation assessment for Bangladesh to climate change and sea level rise. Major climate change impacts and vulnerability assessment studies are (a) Assessment of Vulnerability Bangladesh to Climate Change and Sea Level Rise, (b) Climate Change Country Study Bangladesh under U.S. Climate Change Study Programme, (c) Climate Change and Adaptation Study for Achieving Sustainable Development in Bangladesh, and (d) Country Study on Bangladesh under Regional Study of Global Environmental Issues Project of Asian Development Bank (ADB). Bangladesh has also prepared Initial and Second National Communication in response to the United Nations Framework Convention on Climate Change.

Most of the studies have assessed impacts, vulnerability and adaptation of water, coastal zone, agriculture, infrastructure, forestry and health to climate change and sea level rise. It is found that the vulnerability of the country is a complex interrelationship with biophysical, social, economic and technological aspects. It is revealed that many anticipated adverse impacts of climate change including sea level rise, higher temperatures, enhanced monsoon precipitation and run-off, potentially reduced dry season precipitation, and an increase in cyclone intensity would in fact reinforce many of existing baseline stresses that already pose a serious impediment to the economic development of Bangladesh.

Adverse effects of climate stimuli including variability and extreme events in the overall development of Bangladesh are significant and highly related to changes in the water sector and extreme events (Table 6.1). Most damaging effects of climate change are floods, salinity intrusion, and droughts that are found to drastically affect crop productivity almost every year. Climate change induced challenges are, (a) scarcity of fresh water due to less rain and higher evapo-transpiration, (b) drainage congestion due to higher water levels in the confluence with the rise of sea level, (c) river bank erosion, (d) frequent floods and prolonged and widespread drought, (e) wider salinity in the surface, ground and soil (WB 2000).

Low economic strength, inadequate infrastructure, low level of social development, lack of institutional capacity, and a higher dependency on the natural resource base make the country more vulnerable to climate stimuli including variability and extreme events. It was found that the population living in the coastal area are more vulnerable than the population in other areas. The agricultural sector will face significant yield reduction thus food-grain self sufficiency will be at risk in future (BCAS/RA/Approtec 1994).

Table 6.1 Relationship of climate variability with physical vulnerability context

Climate change					Climate variability			
Increase average temperature	Increase average rainfall	Decrease average rainfall	Sea level rise	Erratic temperature (extreme heat or cold)	Erratic rainfall (excessive rainfall and lack of timely rainfall, untimely rainfall)	Erratic tidal Wave	Cyclone and storm surges	Physical vulnerability context
+	++		++		+	+	+	Inundation
+		++			+			Low flow
			++			++	++	Salt water intrusion
	++				++			Flash flood
++		+++		++	+			Drought
	+		++			++		River morphology

(+) Low, (++) moderate, (+++) high

6.4 National Adaptation Programs of Action (NAPA)

The UNFCCC COP 7 has decided to support the work program for LDCs to prepare and implement national adaptation programs of action (NAPAs), including meeting the agreed full cost of preparation. The NAPAs will communicate priority activities addressing the urgent and immediate needs and concerns of LDCs relating to the adverse effects of climate change. The rationale for developing NAPAs rests on the low adaptive capacity of LDCs, which renders them in need of immediate and urgent support to start adapting to current and projected adverse effects of climate change.

6.4.1 Objectives

The purpose of the NAPA formulation project for Bangladesh was the development of a countrywide program that encompasses the immediate and urgent adaptation activities that address the current and anticipated adverse effects of climate change, including extreme events. The goal of the NAPA formulation for Bangladesh was the provision of a framework to guide the coordination and implementation of adaptation initiatives in the country, through a participatory approach and building synergies with other relevant environmental and related programs. A set of country-driven criteria developed through a consultation process for selecting priority activities to address needs arising from the adverse effects of climate change—The NAPA Team came up with a set of criteria based on various factors (e.g., political, financial, cultural, technical) and a rating/scoring system that was used for objectively selecting/prioritizing the proposed adaptation measures/activities. The NAPA Team could draw on the criteria proposed by the NAPA guidelines in coming up with the set of criteria. This exercise was finalized through an appropriate consultation workshop.

6.4.2 NAPA Preparation Process

Bangladesh National Adaptation Programme of Action (NAPA) was prepared by Ministry of Environment and Forest (2005), Government of the People's Republic of Bangladesh in partnership with relevant specialized Agencies and institutions as a response to the decision of the Seventh Session of the Conference of the Parties (CoP7) of the United Nations Framework Convention on Climate Change (UNFCCC). The preparation process has followed the generic guiding principles outlined in the annotated guideline prepared by LDC Expert Group (LEG). The basic approach to NAPA preparation was along with the sustainable development goals and objectives of the country where it has recognized necessity of addressing environmental issue and natural resource management with the participation of stakeholders in bargaining over resource use, allocation and distribution. Therefore, involvement of different stakeholders was an integral part of the preparation process for assessing impacts, vulnerabilities, adaptation measures keeping urgency and immediacy principle of the NAPA. Policy makers of Government, local representatives of the Government (Union *Parishad* Chairman and Members), scientific community members of the various research institutes, researchers, academicians, teachers (ranging from primary to tertiary levels), lawyers, doctors, ethnic groups, media, NGO and CBO representatives and indigenous women contributed to the development of the NAPA for Bangladesh.

At the highest level there was a Project Steering Committee (PSC) headed by Secretary Ministry of Environment and Forest. The Project Steering Committee is represented by high level officials and experts from different government and non-government organizations to provide guidance. In addition to the Ministry of Environment and Forest, other noteworthy government ministries and agencies involved in the PSC are Ministry of Planning, Economic Relation Division, Ministry of Agriculture, Ministry of Food and Disaster Management, Water Resource Planning Organization, Ministry of Fisheries and Livestock, Ministry of Land, Department of Environment etc. The Project Steering Committee is represented by government, non-government and international research institutes including Bangladesh Institute of Development Studies (BIDS), Bangladesh Forestry Research Institute (BFRI) Bangladesh Centre for Advanced Studies (BCAS), IUCN Bangladesh etc.

The second group of stakeholder is a multi-disciplinary team of experts and sectoral working groups with critical roles and responsibilities to analyse vulnerability of the natural, economic and social systems and connect it will overall development of the country. The six Sectoral Working Groups (SWG) are (a) Agriculture, Fisheries and Livestock coordinated by Bangladesh Agricultural Research Council (BARC), (b) Forestry, Biodiversity and Land-use coordinated by IUCN, Bangladesh, (c) Water, Coastal Zone, Natural Disaster and Health coordinated by Water Resources Planning organization (WARPO), (d) Livelihood, Gender, Local Governance and Food Security coordinated by Bangladesh Institute for Development Studies (BIDS), (e) Industry and Infrastructure coordinated by Department of Environment (DoE), and (f) Policies and Institutes coordinated by Bangladesh Centre for Advanced Studies (BCAS). It was anticipated that participation of key stakeholder in the preparation process will help in mainstreaming adaptation to climate change into national and sectoral development policies and plans as well as implementation of adaptation projects in future. Members of the project steering committee, sectoral working group and experts attended the inception workshop, regional stakeholder consultation workshops, and national stakeholder consultation workshop.

Third group of stakeholders involved in the preparation process were from local and regional (hydro-ecological) level including people from the local government, local level non-government organizations, occupational representations at the grassroots level including farmers and women. The NAPA project has organized regional stakeholder consultation workshops in Rajshahi (north-west region), Khulna (south-west region), Sylhel (north-east region) and Chittagong (south-east region) during December 2004 and January 2005. Drought is a recurrent phenomenon of the north-west region and anticipated that it will increase under changes in climatic system. South-west and south east regions are part of coastal area with salinity, and freshwater availability problems. It is anticipated that salinity intrusion will increase and freshwater availability will decrease in these areas particularly in the dry season. North-east region is a combination of low hills and depressed area and are prone to flash flood.

The objectives of the regional stakeholder consultation workshops were (a) identification of existing problems related to variability, extremes and climate change and rank them if possible, (b) identification of existing coping mechanisms and measures, (c) suggestion for improvement of existing measures, (d) identification of new measures and idea to address anticipated future change in intensity and extent of present problems. The identified problems and suggestions have been incorporated in the sectoral analysis and future programme of action. In addition to the regional stakeholder consultation workshops each sectoral working groups have organized meeting with different sectoral agencies for checking possibility of integration into sectoral policies and plans.

Based on earlier climate change impacts, vulnerability and adaptation studies and regional stakeholder consultation workshops National Consultant Team prepared first draft Bangladesh NAPA, which has been discussed in the National Consultation Workshop. The National Consultation Workshop has discussed all project identified based on local need and are complementary to national development goals and objectives. The National Consultation Workshop has also rank projects using prioritization criteria developed by NAPA team. The national consultant prepared the final Bangladesh.

6.4.3 List of 15 Priority Projects/Measures/Activities Identified in NAPA 2005

The following adaptation measures suggested for Bangladesh to address adverse effects of climate change including variability and extreme events based on existing coping mechanisms and practices, and suggested future strategies and coping mechanism mentioned above. These are categorized into two major types i.e. intervention and facilitating.

Intervention/Facilitating Type Measures

1. Coastal afforestation with community focus to address coastal erosion and protection from enhanced storm surges.
    - 1.1. Community Led Coastal Afforestation Project
    - 1.2. Coastal Afforestation Programme in the Satkhira and Bagerhat Regions of Khulna
    - 1.3. Restoration of the Degraded Forest Ecosystems of the Chittagong Division

2. Promoting adaptation to coastal agriculture (including crops, livestock and fisheries) to combat salinization.
   2.1. Maize Production under Wet Bed No-tillage Method
   2.2. Sorjan systems of cropping in tidally flooded agro-ecosystem
   2.3. Culture of salt tolerant fish special in coastal areas of Bangladesh
3. Providing drinking water to coastal communities to combat enhanced salinity due to sea level rise
   3.1. Development of Strategy for Alternative Sources of Safe Drinking Water
4. Adaptation to agriculture systems (including cropping, livestock, fisheries and tree planting) in areas prone to enhanced flash flooding—North East and Central Region
   4.1. No–tillage potato cultivation under water hyacinth mulch in wet sown condition
   4.2. Vegetable Cultivation on Floating Bed
   4.3. Adaptation to flood on freshwater wetlands (beel) fisheries with special emphasis to recruitment of small indigenous fish species
   4.4. Restoration of Degraded Swamp Forests (haor, baor and beel) in Sylhet
5. Adaptation to agriculture (including cropping, livestock and the poultry) in areas affected by increased drought (North-West)
   5.1. Development and protection of dry season fish refuges for sustainable management of fisheries through community husbandry in the north-western part of Bangladesh
   5.2. Adaptation of fish culture techniques to increased flood levels and diversification of aquaculture techniques in the flood-prone north-central region of Bangladesh
   5.3. Reforestation Programme in the Barendra Region, Rajshahi
   5.4. Development of appropriate cropping pattern for the non-irrigated areas of the Barendra region
6. Enhancing water availability in dry season in North-West Bangladesh due to enhanced temperature and lower rainfall (Water Sector).
   6.1. Development of Strategy for Alternative Sources of Safe Drinking Water
7. Capacity building for modeling, designing of infrastructure and early warning system in water management institutions towards mainstreaming climate change
   7.1. Climate Change Knowledge Gap Filling for Water Resources Planning
   7.2. Capacity Development for Water Sector Managers for Designing Structural Adaptation
   7.3. Development of Negotiating Instruments for Sustainable Drainage Systems
   7.4. Formulation of Land and Water Zonation for Climate Change Adaptation in Bangladesh

   7.5. Development and piloting of strategic Action Plans for the sustainable management of river shad (Hilsa) fisheries in Bangladesh
   7.6. Studies on major carp spawning in the River Halda, Bangladesh with especial reference to meteorological change and habitat degradation
   7.7. Alterative emergency power and water supply

8. Construction of flood shelter to cope with enhanced recurrent floods in major floodplains (Investment project)

   8.1. Construction of Multipurpose Cyclone—Flood Shelters in High Vulnerable Areas
   8.2. Community based Emergency Disaster Shelters and Information and Assistance Centre

9. Exploring options for insurance and other emergency preparedness measures to cope with enhanced climatic disasters (e.g. flood, cyclones and drought).

   9.1. Community based repository of resources (money, food, medicine, energy)
   9.2. Community Disaster Insurance
   9.3. Alterative emergency power and water supply
   9.4. Community based emergency repository for valuable products and equipment
   9.5. Industrial Insurance System for Disasters

10. Mainstreaming adaptation to climate change into policies and programs in different sectors (focusing on disaster management, water, agriculture, health and industry).

   10.1. Formulation of Land and Water Zonation for Climate Change Adaptation in Bangladesh

   10.2. Incorporation of Climate Change Considerations in Standing Order for Disaster (SOD) Preparedness in Bangladesh

   10.3. Introduction of new patterns to the changing landscape due to climate variability

11. Inclusion of climate change issues in curriculum at secondary and tertiary educational institution.
12. Climate change and adaptation information dissemination to vulnerable community to raise awareness.

   12.1. Awareness and Behavioral Change and Communication for Climate Change related Health Problems

13. Promotion of research on drought, flood and saline tolerant varieties of crops to facilitate adaptation in future.

   13.1. Production of High Value Horticultural Crops Round the Year Under Protective Culture

14. Development of eco-specific adaptive knowledge (including indigenous knowledge) on adaptation to climate variability to enhance adaptive capacity for future climate change.
    14.1. Earmarked funding facilitating R&D for water and energy supply
15. Enhancing resilience of urban infrastructure and industries to impacts of climate change including floods and cyclone
    15.1. Particular Specification in National Building Code for building industry and infrastructure in potentially vulnerable areas
    15.2. Community based safe dumping place of the pollutants

Projects prioritization of adaptation were opted based on the criteria as follows: (a) Impacts on Peoples Livelihood (b) Promotion of Improved Health, Welfare and Safety of People, (c) Preservation of Cultural Heritage, (d) Improvement of Delivery and Maintenance of Public Infrastructures and Services, (e) Sustained Availability and Affordability of Basic Needs of People, (f) Reduction of Threats and/or Impacts of Disasters, (g) Preservation of Biological Diversity, (h) Implementation Cost, (i) funding Availability, (j) Project Applicability and (k) Political and Public Support, (l) Reduction of Climate Change Impacts, (m) Political and Public Support, (n) Potential for Adaptation Technology Penetration and Acceptance, (o) Data Availability and (p) Compatibility with National and Sectoral Development Goals

6.4.4 2009 NAPA Updated Version

As a response to UNFCCC, Bangladesh prepared NAPA in 2005. In the meantime Bangladesh experienced super cyclone Sidr (2007) and cyclone Aila (2009). New and emerging literatures on scale of climate change and severity of impacts on cross-sectoral dimensions portray a more vulnerable and frustrating scenario demanding urgent and broad range of actions triggered the Ministry of Environment and Forests to go for updated version of NAPA in 2009. It gave emphasis on four basic national security issues such as (a) food security, (b) energy security, (c) water security and (d) livelihood security. The Ministry of Environment and Forest has engaged all previous six sectoral working groups for updating Bangladesh NAPA. The six Sectoral Working Groups are (a) Agriculture, Fisheries and Livestock coordinated by Bangladesh Agricultural Research Council; (b) Forestry, biodiversity and land use, coordinated by IUCN, (c) Water, Coastal Areas, Natural Disasters and Health Care, coordinated by Water Resource Planning Organization; (d) Livelihood, Gender, Local Governance and Food Security, coordinated by Bangladesh Institute of Development Studies; (e) Industry and Infrastructure coordinated by Department of Environment and (f) Policies and Institutions coordinated by Bangladesh Centre for Advanced Studies. Following is the list of 18 priority projects without any ranking for design and implementations at short and medium term.

6.4.5 Short Term Adaptation Actions

1. Assessment of financial needs to combat climate change
2. Revision of national and sectoral policies to mainstream adaptation to climate change
3. Enhancing resilience of urban infrastructure and industries to impacts of climate change including floods and cyclone
4. Exploring options for insurance and other emergency preparedness measures to cope with enhanced climatic disasters
5. Mainstreaming climate change in national, sectoral and spatial development programs
6. Strengthening human resource capacity
7. Popularization of already released salinity resistant crop varieties
8. Identification of local hotspots for more targeted intervention such as areas most susceptible to moisture stress
9. Impact assessment of Climate Change in the Coastal Region of Bangladesh with possible Adaptation

6.4.6 Medium Term Adaptation Actions

1. Formulation of land zoning legislation and other policy instruments for climate change adaptation
2. Monitoring of climate change impacts on ecosystems and biodiversity
3. Wildlife conservation and management
4. Afforestation including expansion of coastal greenbelt
5. Research on coastal geomorphological changes
6. Management of potentially harmful invasive species
7. Research on land management
8. Restoration of the Sundarbans ecosystem
9. River Response to the Impacts of Climate Change and Strategic Planning of River Erosion Management

6.4.7 Aligning with the Bangladesh Climate Change Strategy and Action Plan (BCCSAP)

The updated NAPA 2009 is well aligned with the BCCSAP (Ministry of Environment and Forest 2008) and would address the following thematic pillars in terms of identifying short and medium term adaptation measures: (a) ensuring food security and pro-poor social protection of the climate vulnerable people; (b) strengthen comprehensive disaster management programme; (c) climate resilient infrastructure development including sustainable cities; (d) mainstreaming climate change in local and national development; (e) capacity enhancement including research and knowledge management and institutional strengthening and (f) strategic natural resource management as an adaptation response to climate change including wise use of wetlands, rivers, flood plain system. Based on these in addition to the original NAPA's set of 15 priority actions, a further 18 priorities have been identified. Overall this updated NAPA of 2009 highlights nine short term priorities mainly addressing the first four pillars, along with nine medium term priorities with focus on the last two thematic pillars of BCCSAP.

References

BCAS, RA, Approtech (1994) Vulnerability of Bangladesh to climate change and sea level rise: concepts and tools for calculating risk in integrated coastal zone management. Bangladesh Centre for Advanced Studies (BCAS), Dhaka

Karim Z, Iqbal MA (2000) Impacts of land degradation in Bangladesh: changing scenario in agricultural land use. Bangladesh Agricultural Research Council, Dhaka

Ministry of Environment and Forest (2005) National Adaptation Programme of Action. MoEF, Dhaka

Ministry of Environment and Forest (2008) Bangladesh Climate Change Strategy and Action Plan. MoEF, GoB, Dhaka

UNFCCC (2009): National Adaptation Program of Action (NAPA). Accessed from: http://unfccc.int/national_reports/napa/items/2719.php

WARPO (2000) National Water Management Plan, main report, vol 2. Ministry of Water Resources, Government of Bangladesh (GoB), Dhaka

World Bank (2000) Bangladesh: climate change and sustainable development. Report No. 21104-BD. Rural Development Unit, South Asia Region, The World Bank, Dhaka

Chapter 7
Bangladesh Climate Change Strategy and Action Plans

Aminul Islam, Rajib Shaw, and Fuad Mallick

Abstract The government of Bangladesh's Vision is to eradicate poverty and achieve economic and social well-being for all the people. This will be achieved through a pro-poor climate management strategy, which prioritizes adaptation and disaster risk reduction, and also addresses low carbon development, mitigation, technology transfer and the mobilization and international provision of adequate finance. The climate Change Action Plan of Bangladesh is built on six pillars: (1) food security, social protection, health, (2) comprehensive disaster management, (3) infrastructures, (4) research and knowledge management, (5) mitigation and low carbon development, and (6) capacity building and institutional strengthening. The BCCSAP (Bangladesh Climate change Strategy and Action Plan) 2009 will be reviewed and revised as further experience and knowledge are gained in implementing adaptation and related research programs as well as new development priorities that may emerge in future. In total, there are 44 programs.

Keywords Adaptation research • Climate change strategy and action plan • Comprehensive disaster management • Institutional strengthening • Mitigation and low carbon development

A. Islam
United Nations Development Programme, Dhaka, Bangladesh

R. Shaw (✉)
Graduate School of Global Environmental Studies, Kyoto University, Kyoto, Japan
e-mail: shaw.rajib.5u@kyoto-u.ac.jp

F. Mallick
BRAC University, Dhaka, Bangladesh

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*, Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_7, © Springer Japan 2013

7.1 Introduction

A strategy to combat climate change represents a fourfold challenge: the climate risk itself and the political will to face up to it, international participation in efforts to tackle climate change, the innovation needed for changes in the production and use of energy, and adaptation of countries to the unavoidable effects of climate change. Based on different country context, the focus and emphasis are of the strategy varies. In general, a strategy should include:

– Extension of action against climate change to all the polluting countries (with common but differentiated responsibilities) and sectors involved (all modes of transport, deforestation etc.);
– Enhanced innovation, which includes the implementation and deployment of existing technologies and the development of new technologies (in particular by means of active support policies which take advantage of normal capital replacement);
– Use and development of market-based instruments; and
– Harnessing of preventive and remedial efforts to adapt to climate change based on the most affected regions and economic sectors.

Apart from developing the action plan, it is required to focus on the following:

– Increased public awareness to encourage people to change their behavior.
– More and better focused research to further improve knowledge on climate change and its global and regional impact and to develop cost-effective climate change adaptation and mitigation strategies.
– Stronger cooperation with other countries at the scientific level and through climate-friendly technology transfer as well as through specific measures with developing countries to draw up climate-friendly development policies and strengthen the adaptive capacity of the most vulnerable countries.

The benefits of a reduction in greenhouse gas emissions stem mainly from the prevention of damage resulting from climate change, such as an increase in sea levels and flooding, greater pressure on drinking water resources, health risks, changes in ecosystems, adverse effects on economies based on agriculture or tourism, increased likelihood of fires and extreme weather events (storms, heat waves), resulting increase in insurance costs and expenditure etc. It is however difficult to put a precise figure on the benefits of such action. Moreover, not all regions or economic sectors within the country will be equally affected. The costs of action are also difficult to evaluate. They would result mainly from the restructuring of transport systems and energy production and use. Moreover, these costs would increase significantly if no action is taken by the other major producers of greenhouse gas emissions.

With this background, this chapter provides a brief outline of Bangladesh Climate Change Strategies and Action Plan.

7.2 Bangladesh CC Action Plan

Bangladesh is one of the most climate vulnerable countries in the world and will become even more so as a result of climate change. Floods, tropical cyclones, storm surges and droughts are likely to become more frequent and severe in the coming years. Many would say that the signs of the future changes have already begun to become apparent. These changes will threaten the significant achievements Bangladesh has made over the last years in increasing incomes and reducing poverty, and will make it more difficult to achieve the MDGs. It is essential that Bangladesh prepares now to adapt to climate change and safeguard the future well-being of its citizen. Indeed, the new democratic government is unequivocal in its commitment to protect the people from the ravages of climate change as stated clearly in its election manifesto.

Over the last 35 years, the Government of Bangladesh has invested over $10 billion to make the country less vulnerable to natural disasters. These investments, in many cases supported by development partners, include flood management schemes, coastal polders, cyclone and flood shelter, and the raising of roads and highways above flood level. In addition the government of Bangladesh has developed state-of-the-art warning systems for floods, cyclones and storm surges and is expanding community-based disaster preparedness. Climate resilient varieties of rice and other crops have also been developed.

The challenge Bangladesh now faces is to scale up these investments to create a suitable environment for the economic and social development of the country and to secure the well-being of the people, especially the poorest and most vulnerable groups, including women and children.

The government of Bangladesh's Vision is to eradicate poverty and achieve economic and social well-being for all the people. This will be achieved through a pro-poor climate management strategy, which prioritizes adaptation and disaster risk reduction, and also addresses low carbon development, mitigation, technology transfer and the mobilization and international provision of adequate finance.

Sections I–V of the document provide the context, outline the implications and likely impacts of climate change in Bangladesh, provide an overview of different adaptation strategies and briefly outline mitigation issues. Sections VI and VII describe a 10 year programme to build the capacity and resilience of the country to meet the challenges of climate change over next 20–25 years.

The climate Change Action Plan is built on six pillars:

1. Food security, social protection and health to ensure that the poorest and most vulnerable in society, including women and children, are protected from climate change and that all programmes focus on the needs of this group for food security, safe housing, employment and access to basic services, including health.
2. Comprehensive disaster management to further strengthen the country's already proven disaster management system to deal with increasingly frequent and severe natural calamities.

3. Infrastructure to ensure that existing assets (e.g. coastal and river embankments) are well-maintained and fit-for-purpose and that urgently needed infrastructure (e.g. cyclone shelters and urban drainage) is put in place to deal with the likely impacts climate change.
4. Research and knowledge management to predict the likely scale and timing of climate change impacts on different sectors of the economy and socioeconomic groups; to underpin future investment strategies, and to ensure that Bangladesh is networked into the latest global thinking on science, and best practices of climate change management.
5. Mitigation and low carbon development to evolve low carbon development options and implement these as the country's economy grows over the coming decades and the demand for energy increase.
6. Capacity building and institutional strengthening to enhance the capacity of government ministries and agencies, civil society and the private sector to meet the challenge of climate change and mainstream them as part of development actions.

The needs of the poor and vulnerable, including women and children, will be prioritized in all activities implemented under the action plan. The climate change action plan comprises immediate, short, medium and long-term programmes.

7.3 Implementation Context

The climate change action plan will be implemented under the overall guidance of the National Environment Committee, chaired by the Prime Ministry of Environment and Forests. Programs funded under the plan will be implemented by concerned Ministries or their agencies, with the involvement, as appropriate, of civil society and the private sector. The Climate Change Strategy and Action Plan 2009 is the revised version of the initial document with the same title prepared in 2008. The initial document had been developed in 2008 by the then Government of Bangladesh in consultation with civil society, including NGOs, research organizations, the private sector and development partners. The initial (2008) and the revised (2009) Climate Change Strategy and Action Plan build on and substantially expands the National Adaptation Programme of Action (NAPA), published in 2005. The BCCSAP 2009 will be reviewed and revised as further experience and knowledge are gained in implementing adaptation and related research programs as well as new development priorities that may emerge in future.

There are 44 programs listed in the BCCSAP. The annotations for justification, the kind of activities to be undertaken and the responsible ministries/agencies for each of the programme within the six pillars outlined above is also provided in annex. These programs would be elaborated with all details in consultation with the stakeholders at the time of their planning and implementation. This list of programs is by no means exhaustive It only outlines the first set of activities that are to be undertaken in the line with the needs of the communities and the overall development program of Bangladesh as follow:

Theme: T1: Food Security, Social Protection and Health

P1. Institutional capacity for research towards climate resilient cultivars and their dissemination
P2. Development of climate resilient cropping systems
P3. Adaptation against drought
P4. Adaptation in fisheries sector
P5. Adaptation in livestock sector
P6. Adaptation in health sector
P7. Water and sanitation programme in climate vulnerable areas
P8. Livelihood protection in ecologically fragile areas
P9. Livelihood protection of vulnerable socio-economic groups (including women)

Theme: T2: Comprehensive Disaster Management

P1. Improvement of flood forecasting and early warning
P2. Improvement of cyclone and storm surge warning
P3. Awareness raising and public education towards climate resilience
P4. Risk management against loss on income property

Theme: T3: Infrastructure

P1. Repair and maintenance of existing flood embankments
P2. Repair and maintenance of cyclone shelters
P3. Repair and maintenance of existing coastal polders
P4. Improvement of urban drainage
P5. Adaptation against floods
P6. Adaptation against tropical cyclones and storm surges
P7. Planning and design of river training works
P8. Planning, design and implementation of resuscitation of river and khals through dredging and de-siltation work

Theme: T4: Research and Knowledge Management

P1. Establishment of a center for knowledge management and training on climate change
P2. Climate change modeling at national and sub-national levels
P3. Preparatory studies for adaptation against sea level rise
P4. Monitoring of ecosystem and biodiversity changes and their impacts
P5. Macroeconomic and sectoral economic impacts of climate change
P6. Monitoring of internal and external migration of adversity impacted population and providing support to then through capacity building for their rehabilitation in new environment
P7. Monitoring of impact on various issues related to management of tourism in Bangladesh and implementation in priority action plan

Theme: T5: Mitigation and Low Carbon Development

P1. Improved energy efficiency in production and consumption of energy
P2. Gas exploration and reservoir management
P3. Development of coal mines and coal fires power stations
P4. Renewable energy development
P5. Lower emission from agricultural land
P6. Management of urban waste
P7. Afforestation and reforestation programme
P8. Rapid expansion of energy saving devices e.g., Compact Florescent Lamps (CFL)
P9. Energy and water efficiency in built environment
P10. Improvement in energy consumption pattern in transport sector and options for mitigation

Theme: T6: Capacity Building and Institutional Strengthening

P1. Revision of sectoral policies for climate resilience
P2. Main-streaming climate change in national, sectoral and spatial development programme
P3. Strengthening human resource capacity
P4. Strengthening gender consideration in climate change management
P5. Strengthening climate change in the media

Following parts show representatives examples of actions in six different themes.

Appendix

See Figs. 7.1–7.6.

Programme – T1P1

Theme	T1. Food Security, Social Protection and Health
Programme	P1. Institutional capacity and research towards climate resilient cultivars and their dissemination
Objective	To build the institutional capacity of research centres and expertise of researchers to develop climate resilient cultivars of food and other crops
Justification	Global warminwg will alter the ambient conditions under which crops grow. Initially, higher temperatures and increased concentrations of carbon dioxidemay increase food grain yields due to increased photosynthesis. However, temperatures are predicted to increase by over 2°C and carbon dioxide concentrations to exceed more than 450 ppm, which will reduce yields of current cultivars of cereals, such as rice and wheat. In addition, increased droughts, floods and saline intrusion, in different parts of the country, will also cause crop losses Researchwork has started at BRRI, BARIandotherresearchcentresunderNARS to develop cultivars adapted to likely future climatic conditions. There is an urgent need to develop the research capacity of these institutes and scientists, and to provide better research facilities The impact of climate change on many other food (e.g., potatoes) and non-food crops (e.g., jute) is largely unknown. Research must be initiated to understand these impacts and find out how to minimise adverse changes It takes 7-8 years to breed new cultivars, certify them and release to the farmers through the extension system. In view of this, indigenousvarieties will be screened to identify those that can withstand, at least partially, the adverse impacts of climate change on yields. After participatory field trials, they will be disseminated to farmers
Actions	A1. Collection and conservation of local improved cultivars, characterization and their documentation A2. Research to develop climate resilient varieties of rice (i.e., heat, drought, salinity and submergence tolerant varieties) A3 Research to develop climate resilient (i.e. heat, drought, salinity and submergence tolerant) cultivars of wheat and other food and non food crops including vegetables A4 Field trials and disseminations of the climate resilient local improved cultivars and the newly developed varieties, to farmers in partnership with the DAE and NGOs A5. Strengthening the capacity of NARS institutes, research facilities and Scientists and Technicians to undertake the work
Timeline	Medium to Long term
Responsibility	BRRI, BARI and other NARS organisation

Fig. 7.1 Institutional capacity for food security, social capital and health [T1P1]. *Source*: BCCSAP (2009)

Programme – T2P1

Theme	T2. Comprehensive Disaster Management
Programme	P1. Improvement of flood forecasting and early warning systems
Objective	Improvement of the existing flood forecasting and early warning systems by increasing lead times and strengthening dissemination mechanisms
Justification	Bangladesh is highly regarded for its competence in flood forecasting and early warning systems. Currently, the Flood Forecasting and Warning Centre (FFWC) of the Bangladesh Water Development Board (BWDB) issues flood levels forecasts for 24, 48 and 72 hours. These forecasts are released through e-mails as well as placed on a web-site. However, there is scope for improvement 1. Dissemination. The current practice of releasing warnings in terms of river stage are not easily understood by local communities, while the absence of digital elevation models (DEM) makes it difficult for flood forecasting modellers to relate river stage to likely flood levels at different locations in the countryside. T3P5, below, would develop a DEM for areas vulnerable to floods. It is important that this is used by flood forecasters, together with information on river stages to improve forecasts for floodplain communities 2. Lead times. It would be helpful to communities and the authorities to have longer range forecasts, even though they are not always reliable. FFWC has the capacity to make 10 day forecasts. It should be encouraged to do so and the usefulness of the new forecasts assessed
Actions	A1. Review of the hydro-meteorological data network and the setting up of telemetric stations A2. Improvement in dissemination of warnings by (a) combining river stage and DEM information; and (b) making 10 day forecasts A3. Awareness building programmes at community level on warnings produced and released by FFWC
Timeline	Immediate and continuing
Responsibility	Ministry of Water Resources and its various agencies; civil society organizations active in disaster management and media

Fig. 7.2 Improvement of food forecasting and early warning system for comprehensive disaster management [T2P1]. *Source*: BCCSAP (2009)

Programme – T3P1

Theme	T3. Infrastructure
Programme	P1. Repair and maintenance of existing flood embankments
Objective	Ensure continued flood protection by repairing and rehabilitating existing flood embankments
Justification	Earthen embankments have been constructed by the Bangladesh Water Development Board (BWDB), along most major and medium-sized rivers in the country and also some minor rivers. They are the key structural component of the flood management system in the country The heights of the embankments were designed based on recent major floods and/or statistical analysis of past river stage data. For embankments along major rivers a 50 year return period was used. For protection of Dhaka city, the level of safety was a 100 year flood Many of these embankments are in poor shape due to lack of proper maintenance. In many places the embankments are cut by local people to drain water from the land into the rivers. Although these gaps are filled in again, these points remain vulnerable to breaches. In many places the appurtenant structures, such as sluices and regulators no longer function properly Embankments have provided security from flooding and, as a result, many people have moved into protected floodplain areas. The traditional approach of building homes on raised mounds has more or less been abandoned. Farmers go for high yielding variety of crops because of the security provided by the embankment and associated drainage systems. Given this, it is very important to rehabilitate existing river flood embankments so that they are fully functional and able to provide the level of security for which these were constructed
Actions	A1. Assess the condition of all existing flood embankments and prepare GIS maps A2. Immediate repair and rehabilitation of existing embankments and appurtenant structures taking future forecast flood levels into account
Timeline	Immediate
Responsibility	Ministry of Water Resources and its agencies

Fig. 7.3 Repair and maintenance of existing flood embankments in infrastructure [T3P1]. *Source*: BCCSAP (2009)

Programme – T4P1

Theme	T4. Research, and Knowledge Management
Programme	P1. Establishment of a centre for research, knowledge management and training on climate change
Objective	To increase institutional and human capacity on research and knowledge management related to climate change, and to train sector professionals
Justification	Although Bangladesh has been in the forefront of awareness raising on adaptation and on-the-ground adaptation research, the knowledge and information generated remains scattered. A comprehensive move towards adaptation and mitigation supported by technology transfer and financial flows (as envisaged in the BCCSAP) requires an up-graded system of knowledge creation, dissemination and training Bangladesh has already suggested that an International Adaptation Research and Training programme should be established in the country as an international public facility for all to draw upon. While this may be an ultimate goal, a more urgent need is to set up a centre or network of institutions to be (a) a source of all available national information, reports and knowledge, and (b) a virtual technology bank, including on financial mechanisms related to both adaptation and mitigation. It would also track and provide information on the state of climate change negotiations A dedicated web portal would be established, which would track all national and within country policies, rules and regulations, and news related to climate change debates. The information managed by the Centre will be available to the public. In essence, it would be a one-stop data and information bank on climate change for all related national activities The Centre would also arrange for training programmes on issues related to adaptation and mitigation and would support activities in collaboration with universities, research centres and other agencies
Actions	A1. Establish a centre and/or network for research on climate change and climate change impacts and their management A2. Establish a virtual technology bank A3. Develop and maintain a dynamic web portal A4. Develop training programmes for high and mid-level officials of the Government, NGOs and private organisations/associations and provide training in collaboration with research centres and universities
Timeline	Immediate and continuing
Responsibility	Ministry of Environment and Forests, research organisations, universities

Fig. 7.4 Establishment of a center under theme Research and Knowledge Management [T4P1]. *Source*: BCCSAP (2009)

Programme – T5P1

Theme	T5. Mitigation and Low Carbon Development
Programme	P1. Improved energy efficiency in production and consumption of energy
Objective	Ensure an energy secure and low-carbon development of the economy
Justification	Bangladesh is one of the lowest energy consuming and green house gas (GHG) emitting countries. Our energy consumption is around 90 kgoe (kilogramme of oil equivalent) per capita, the lowest in South Asia except for Nepal. We use 170 Kwh electricity per capita which is equivalent to 38 kgoe.We emit less than one-fifth of 1 percent of the total global emission of carbon dioxide equivalent in the world However, Bangladesh is also an energy-inefficient country. If we raise the efficiency with which we produce and consume energy, we may be able to increase energy supply while lowering carbon emission. This could allow us to lower carbon emissions without jeopardizing energy security and growth We should carefully assess how we can become more efficient in producing and consuming energy. This will involve identifying any technical, economic or regulatory/policy constraints to help improve performance and to learn how these constraints can be overcome. Improving our efficiency may require the use of new technologies which could be costly and will thus need additional financial resources It will be important to take a medium to long-term view in analysing alternative investments since, once investments are made, it would be expensive to change them
Actions	A1. Study the future energy needs of the country and find out the least cost energy supply path that satisfies future energy demand based on the desired growth path of the economy A2. Raise energy efficiency in power production, transmission and distribution through appropriate investments A3. Raise energy efficiency in agricultural and industrial processes through appropriate policies and investments A4. Raise energy efficiency in domestic and commercial/service sectors through appropriate policies and investments A5. Raise energy efficiency in transport sector through appropriate policies and investments
Timeline	Medium to long term
Responsibility	Ministry of Power, Energy and Mineral Resources, Ministry of Industry, Ministry of Agriculture, Ministry of Communications, Ministry of Finance, Universities and Research Organisations

Fig. 7.5 Improved energy efficiency in production and consumption under the theme mitigation and low carbon development [T5P1]. *Source*: BCCSAP (2009)

Programme – T6P1

Theme	T6. Capacity Building and Institutional Strengthening
Programme	P1. Revision of sectoral policies for climate resilience
Objective	To integrate climate change issues into development policy and action
Justification	The Government and the people of Bangladesh realise that climate change is going to impact adversely on many sectors and threatens the nation's economic and social achievements. Our food, water, energy and livelihood (including health) security are threatened. An integrated approach is needed to counter this. Climate change management needs to be integrated into the development activities of different sectors. Sectoral policy statements need to be modified to take account of and become consistent with climate change impacts and their management The National Water Management Plan recognizes the need to make water sector activities resilient to climate change. However, the only sectoral policy that explicitly incorporates climate change considerations is the Coastal Zone Policy of Bangladesh, which was drafted in 2005 when knowledge and understanding about climate change was available There is also a need for a National Climate Change Policy to guide the integration of climate change issues into development planning and to provide a framework for sectoral policies. All policy formulation should be carried out in a consultative way by involving key officials of concerned ministries/sectors together with professionals, academics, NGOs and civil society leaders, as well as the general public
Actions	A1. Draft a consultation paper on the National Climate Change policy, the integration of climate change issues into development planning and sectoral policies and how they should be formulated for discussion with key stakeholders A2. Incorporate climate change concerns in all sectoral policies and strategies through appropriate revisions in consultation with relevant stakeholders A3. Publish the National Climate Change Policy
Timeline	Immediate
Responsibility	Ministry of Environment and Forests, Cabinet division

Fig. 7.6 Revision of sectoral policies for climate resilience under theme capacity building and institutional strengthening [T6P1]. *Source*: BCCSAP (2009)

Reference

BCCSAP (2009) Bangladesh Climate Change Strategy and Action Plan. Government of Bangladesh, Dhaka, 48 pp

Part III
Socio-Economic Impacts

Chapter 8
Multi Hazard Vulnerabilities of the Coastal Land of Bangladesh

Md. Golam Mahabub Sarwar and Aminul Islam

Abstract This study assessed the vulnerability of the coastal lands of Bangladesh using secondary resources. The research revealed that coastal land within the country is threatened by saltwater intrusion, erosion–accretion, land subsidence, water logging, cyclones, storm surges and tidal flooding. A 1-m sea-level rise will inundate 17.5 % of Bangladesh's landmass along the coastal zone, affect 20 % of the country's rice fields and threaten the UNESCO declared world heritage site, the Sundarbans. Coastal soil will be affected by salinity intrusion at more rapid rate than coastal water. The six districts of Jessore, Magura, Narail, Faridpur, Gopalgonj and Jhalokhati have been affected by new salinity intrusion over the 24 year period of 1973–1997 and the loss in agriculture from salinity induced coastal land degradation could be as high as USD 587 million. Over a period of 20 years, the south central coast has accreted at a rate of 7.0 km^2/year near the Ganges–Brahmaputra–Meghna (GBM) mouth and the southwest coast has been eroding at a rate of 1.9 km^2/year. During this period, the coastal land has also been subsiding at a rate of 4 mm/year. A total of 19,670 ha of saltpan in the Cox's Bazaar district of the Southeast coast is vulnerable to storm surges and vast agricultural lands of the Southwest and south-central coast of the country are highly vulnerable to tidal flooding and storm surges. Assessing vulnerability at a local level and formulating adaptation policies are both priority areas in formulating sustainable management options for the coastal lands of Bangladesh.

Keywords Bangladesh • Coastal land • Coastal zone • Sea-level rise • Vulnerability

---

Md. G.M. Sarwar (✉)
Bangladesh Unnayan Parishad (BUP), Dhaka, Bangladesh
e-mail: mgmsarwar@gmail.com

A. Islam
United Nations Development Programme, Dhaka, Bangladesh

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*,
Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_8, © Springer Japan 2013

8.1 Introduction

Vulnerability is the prospective loss due to environmental hazard or natural disaster. It has arisen as central part of climate change debate since many years and its concept is amending with the passing of time. Coastal zones are particularly vulnerable because of its dynamic environmental settings. As a low-lying country, Bangladesh is highly vulnerable to sea-level rise (SLR) (Milliman et al. 1989; Ortiz 1994; Ali 1996; 2000; Choudhury et al. 1997; Sarwar and Khan 2007; Karim and Mimura 2008). In spite of great concern about SLR impacts on Bangladesh, few studies have focussed on assessing the rate of or the impacts of SLR for this coast. The wide discussion of sea-level rise impacts on Bangladesh has largely arisen from a general conception about the low-lying elevation of the coastal zone of the country. In addition, the coastal zone of Bangladesh is very dynamic in terms of erosion and accretion. An overall trend of accretion in the south-central zone and erosion in the Sundarban is suggested by many studies (Allison 1998; Allison and Kepple 2001; Mikhailov and Dotsenko 2007). Besides SLR and erosion–accretion, coastal land of the zone is vulnerable to multiple natural and man-made hazards including subsidence (Morgan and McIntire 1959; Goodbred and Kuehl 1998; Worm et al. 1998; Stanley and Hait 2000), flooding (Paul and Rasid 1993; Islam and Sado 2000; Choudhury et al. 2004), cyclone (Khalil 1992, 1993; Karim 1995; Alam et al. 2003; Islam and Peterson 2009), salinity intrusion (Potten 1994; Alexander et al. 1998; Chowdhury and Karim 1998; Mondal et al. 2001; Haque 2006; Miah et al. 2007), and land transformation (Ali 2003; Hossain et al. 2003; Ali 2006; Iftekhar 2006; Bala and Hossain 2009; Siddique and Volpe 2009). However, a combination of vulnerabilities of all the mentioned hazards is yet to be done. This paper reviews multi-hazard vulnerabilities of coastal land of Bangladesh.

8.2 Coastal Zone of Bangladesh

The shoreline is defined in different way by different researchers (Boak and Turner 2005) and the coastal zone is even difficult to delineate. The coastal zone of Bangladesh is delineated by different agency purposively to serve their particular work. Soil Resources Development Institute (SRDI) defines the coastal zone as the area affected by tidal water of the Bay of Bengal that could be extended up to 150 km landward from the coast, whereas the Department of Public Health and Engineering (DPHE) treats the coastal zone as the area where salinity intruded into superficial or deep aquifers (Uddin and Kaudstaal 2003). From a coastal zone management point of view, the delineation of the coastal zone was done by the Ministry of Water Resources, and the 6th meeting of the Inter-ministerial Technical Committee for the Integrated Coastal Zone Management Plan defined the coastal zone of the country as the total area of 19 coastal districts that are again subdivided into 147 upazillas, including the Exclusive Economic Zone (MoWR 2003). A total of 48 out of 147 upazillas of 12 districts meet the sea directly and defined as exposed

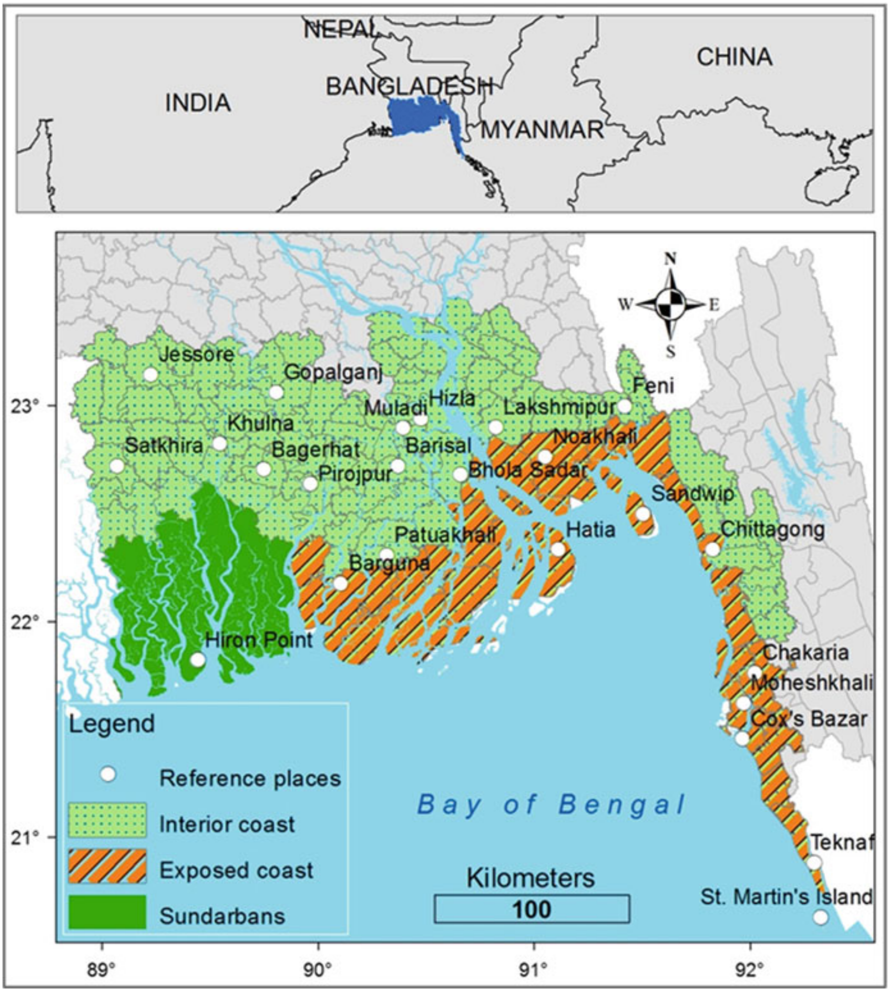


Fig. 8.1 Coastal zone of Bangladesh. The Sundarbans is included in the exposed coast. Places marked in the map have been referred in text

coast, and rest of the upazillas are defined as interior coast (Uddin and Kaudstaal 2003) (Fig. 8.1).

The coastal area of Bangladesh can be divided into three distinct zones; the southwest, south central and southeast zone. The southwest and south-central zones are low in elevation height and flat in nature. The southwest zone extends from Bangladesh–India Border to the Haringhata River Estuary. More than 65 % of the Sundarbans—the biggest single-strand of mangrove forest on the earth is located in this part of the coast, covering an area of 4,950 km^2 (Blasco et al. 2001; Iftekhar 2006). The coastal area of Satkhira, Khulna, Bagerhat and Pirojpur districts belongs to the southwest coast. The deep sea canyon Swatch of No Ground (SONG) is only

24 km away to the south from this coast. The south-central coast covers the lower part of the Meghna River extending from the Haringhata River Estuary to the Feni River Estuary. The zone is formed of the coastal area of Barguna, Patuakhali, Bhola, Lakshmipur, Noakhali and Feni districts. The southeast zone is narrow and dominated by narrow hills and uplands, extending from the Feni River Estuary to the southernmost tip of the country. A narrow sandy sea beach of Teknaf having an unbroken length of 120 km, and Cox's Bazar and Patenga sea beach falls within the zone. The zone is formed of the coastal area of Chittagong and Cox's Bazar district. There are about 100 islands in this zone scattered mainly in the southwest and south-central part. Continuous erosion and accretion processes are forming new islands, while others are also disappearing, resulting in a dynamic number of islands on the coast. Bhola district composes the biggest island located at the Meghna.

River Estuary, whereas the St. Martin's island located at the south-eastern corner is the only island fringed by coral reef.

The coastal zone consists of an area of 47,201 km^2 containing a total of 46 million people. A total of 9.2 % of area of the GBM delta located to the south of 23°N has <2 m of elevation height (Woodroffe et al. 2006) and most of which covers Bangladesh part of the delta, especially the south-central and the southwest coastal zone of the country. McGranahan et al. (2007) ranked Bangladesh as the third country in the world in terms of hosting population in Low Elevation Coastal Zone (LECZ) for its total population of 62,524 after China and India. Forty six percent of population of the country live in LECZ and Bangladesh was placed as the sixth in the world in terms of population living in the zone. The coastal zone of Bangladesh covers a total of 2.85 million hectares of cultivable land (Bala and Hossain 2009) and represents 20 % of the rice acreage of the country (Begum and Fleming 1997).

8.3 Vulnerabilities of Coastal Land

8.3.1 Sea-Level Rise (SLR)

Based on global trend Choudhury et al. (1997) postulated a sea-level rise of 10–15 mm/year along the Bangladesh coast that seems to be an underestimation compare to 4–7.8 mm/year assessment of Singh (2002). Monthly mean sea level (MSL) of Bangladesh coast is highest during the period of June–August when river discharge is highest because of peak rainfall in the country and also in the upstream countries, whereas MSL is lowest during January–March. The seasonal variation of MSL varies from 0.3 to 0.5 m observed by Khandker (1997). On the other hand, Khan et al. (2000) reported high seasonal variation in the trend of mean tidal level from 2.5 mm/year in May to 8.5 mm/year in November at Hiron Point and 4.3 mm/year in May to 10.9 mm/year in November at Cox's Bazar.

A study of sea-level trend in Bangladesh was initiated by Singh (2002) who showed spatial variation using tide gauge data over 22 years, for the period of 1977–1998, from Hiron Point, Char Changa (Hatia) and Cox's Bazar stations on the

Fig. 8.2 Erosion in the southeast coastal area

southwest, central and southeast coast of Bangladesh, respectively. He found a wide variation in the change of sea level along the coast. Changes were highest in Cox's Bazar with a rate of 7.8 mm/year and the second and the third rates of trend were at Char Changa and Hiron Point at the rate of 6.0 and 4.0 mm/year respectively.

A sensitivity analysis by Begum and Fleming (1997) showed that a 1.4 m rise in sea level in the Bay of Bengal (BOB) may raise the water level of the Meghna River Estuary (MES) to about 6 m, causing inundation of surrounding area. The same study mentioned that even a 0.2 m SLR in the BOB may lead to 4.5–6 m rise in water level of MES. Ali (2000) reviewed that an SLR of 0.1, 0.3, and 1.0 will result a permanent inundation of 2,500, 8,000 and 14,000 km^2 of land, corresponding to 2 %, 5 %, and 10 % of landmass of the country. Furthermore, the impacts of 1-m SLR by World Bank (2000) estimation is even higher projecting an affect to 17.5 % of country's landmass with a complete destruction of the Sundarbans.

8.3.2 Erosion and Accretion

Erosion (Fig. 8.2) and accretion are common features of the Bengal Basin. The Ganges–Brahmaputra–Meghna (GBM) system delivers an estimated load of 1 billion tons of sediment of which roughly 30–40 % is distributed within the Bengal Basin and never reaches the shelf area (Goodbred and Kuehl 1998) resulting in an accretion in the basin. On the other hand, tidal forces and wave action cause erosion that keeps the coast dynamic. Allison and Kepple (2001) estimated a total of 3.7×10^7 t/year of sediment accumulation in the Sundarbans region from the coastline to 75 km landward in a south–north direction. On the other hand, the area of the coastal zone between the Haringhata and Meghna River estuaries received a sediment accumulation of 3.8×10^7 t/year. Sediment accumulation in the delta front of the Sundarbans should have experienced an accretion of land where, in contrary, erosion has been observed by many researchers. Continuous sediment accumulation and erosion observed in the same area has drawn attention of researchers about the dynamics of the zone.

A study by Allison (1998), using geographic information system (GIS) technology, calculated that the shoreline in the western Sundarbans region has eroded at an average rate of 20 m/year during the period 1970–1990. Comparing the 1792 chart, the 1840 survey report of the Sundarbans, Admiralty Charts of 1904 and 1908, and Landsat image of 1984, he demonstrated an accretion rate of 7.0 km^2/year near the GBM mouth, east of the Haringhata River during the period of 1792–1984. In contrast, the area west of the Haringhata River estuary was eroded at a rate of 1.9 km^2/year. A net 1,346 km^2 of land was accreted east of the river mouth during the period and the land loss due to erosion in the western delta front was calculated as 368 km^2. Allison (1998) suggested that the erosion in the delta front of the Sundarbans is due to a lack of sediment in the area caused either by the eastward migration of the GBM mouth or because of lower sediment delivery from upstream by the local tributaries of the Ganges.

It is a tidal dominated system and a significant part of it lies within the contour area of less than 3 m (Allison 1998; Coleman et al. 2008). The southwest coastline was almost stable up until 1980s since Rennel's map of 1776 (Stoddart and Pethick 1984, p. 341). However, erosion in the western coast observed by some recent studies (see Allison 1998; Allison and Kepple 2001; Mikhailov and Dotsenko 2007) indicates dramatic change in the region. The future of the GB delta depends on multidimensional complex factors, including sediment supply from upstream, local land subsidence; changes in local sea level and excess use of water in the upstream, which all affect sediments flow towards the Bay of Bengal (Nicholls and Goodbred 2004). Construction of a dam in the upstream area greatly influences the normal flow of water and traps sediment causing less sediment discharge towards downstream. Reduced sediment supply will not be able to replenish the land loss of the region due to erosion and subsidence.

A study by Ghosh et al. (2001) assessed the shoreline changes of Indian Sagar Island, located in the Hoogly River estuary that observed an increase in erosion rate. The island showed an erosion rate of 4.45 and 18.75 m/year during 1989–1995 and 1995–1999 respectively indicating fourfold higher erosion during the later period. It was later confirmed by another study by Kumar et al. (2007) that compared satellite data of 1998 and 1999 and estimated an erosion induced land loss of 3.18 km^2 of the same island in just 1 year time. A further study by Mukherjee (2007) using RS and GIS technique, observed a decreasing trend of the areas of islands of the southern part of the Indian Sundarbans. The geological and ecological settings of the Sundarbans in Bangladesh and India are alike, and erosion in Indian Sundarbans indicates that a similar state prevail is likely to in Bangladesh part. A change detection study using Remote Sensing technique by Islam et al. (1997) observed a land accretion of 12.00 km^2 during the period of 1933–1987 in the Sharankhola Island that covers an area of 75 km^2 and is located at the south-eastern corner of the Sundarbans.

8.3.3 Subsidence

Subsidence in the region is an important issue but yet difficult to determine accurately and it varies geographically. The rate of subsidence of the delta has been calculated as considerably different by different researchers (Morgan and McIntire 1959; Goodbred and Kuehl 1998; Worm et al. 1998; Stanley and Hait 2000). Analysing a collection of evidence and comparing two courses of the Brahmaputra River, Morgan and McIntire (1959) reported high subsidence activities in the coastal zone averaging around 15 m in the Khulna region and 5 m in the Coastal region of Sundarbans in the last several hundred years, which seems to be an over estimation compare to other studies.

Subsidence estimation by MPO (1985, cited in Hoque and Alam 1997) ranged from 0.6 to 5.5 mm/year but could be as high as 20 mm/year in the Surma Basin and 30 mm/year in the Hatiya Trough. Based on radiocarbon dates, Umitsu (1993) suggested that the coastal zone of Bangladesh, especially the Khulna region is subsiding at a rate of 4 mm/year. Hoque and Alam (1997) reported evidence of subsidence by an observation of the ground floor of a very old building positioned a few feet below the land surface. On the basis of Recent and Pleistocene boundary they estimated a subsidence rate of 2.44 cm/year at Hazipur, located near the Brahmaputra River in Jamalpur District and 2.0 cm/year at Hizla–Muladi, located on the south central coast of Bangladesh. A study by Singh (2002) suggested a subsidence rate of 4 mm/year on the east coast of Bangladesh during the period 1977–1998. In contrast, uplift is occurring in the eastern coast of the country. A study by Khan et al. (2005) observed uplift on the eastern coast of Bangladesh at a rate of 3.6 mm/year in a coastal island Maiskhali Anticline during 18 ka-present and 2.86 mm/year in Jaldi anticline on the mainland between 35 ka and present.

8.3.4 Flood

Flood is a recurring experience in Bangladesh. High rainfall in the monsoon, low land elevation, river-bed sedimentation, backwater effect, and flood-control activities are major dominating factors for flooding in Bangladesh. In normal situation, 21.5 % of the country's landmass is flooded (Mirza et al. 2001), which could be extended to as much as to 69 % in 1998 (Ali 2007) that was considered as mostly affected flood of national history. Out of 64, a total of 52 districts were affected by the flood of 1998 that had a persistence of 74 days, with a national economy loss of US$1.4 billion (Mustafi and Azad 2003). Vast area of the country is flooded annually (Fig. 8.3).

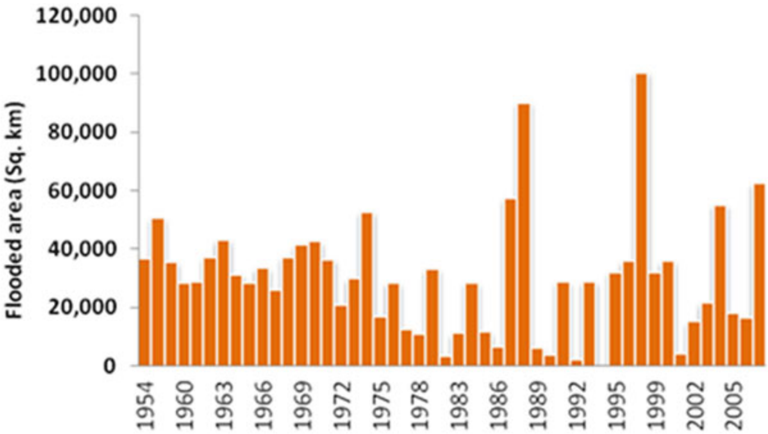


Fig. 8.3 Flood affected area of Bangladesh since 1954–2005 (data source: BWDB)

Having low-lying elevation, the coastal zone of the country is subject to different type of floods. The south and south-central coastal zone is dominated by rainfall flood attributed by intense rainfall when input flow of water is greater than the drainage capacity, whereas the south-eastern coast is dominated by flash flood endorsed by heavy rainfall in the hilly area of the zone resulting short-time flood in the foothill area. The zone is also subject to tidal flooding dominated by tidal water. Fifty percent of coastal lands are featured with permanent or temporary inundation that reduces the effectiveness of coastal land (Islam 2006). Inundation is caused by both man-made and natural grounds. Paul and Rasid (1993) studied district level flood damage to rice crops in Bangladesh from 1967 to 1988 that revealed that rice production of Bagerhat, Barisal, Bhola, Chittagong, Cox's Bazaar, Feni, Khulna, Noakhali, , Patuakhali, and Satkhira districts were affected by flood.

The South-eastern coastal zone is affected by flash flood. The severity of flash flood was also enhanced by man-made structure. Choudhury et al. (2004) studied the impacts of coastal embankments on flash flood of south-eastern coast and found an increase both in flood depth and longevity in Chokoria Thana, a coastal sub-district of the zone, after the construction of embankment. They found that the affect of flash flood increased after the building of coastal embankments in the 1980s that was even exaggerated after its rebuilding in stronger structure, after the storm surge in 1991.

A flooding event may affect the whole of the coast. The flood of 1998 caused damage to 1.6 million hectares of cropland, A study by Islam and Sado (2000) developed a flood hazard map for the whole of Bangladesh that revealed the flooding extent of 1988 flood for administrative districts showing that coastal districts could be flooded as much as 93 % land area of the district, as was in Gopalganj, with an average flooding extent of 35.03 % of whole coastal area.

Tingsanchali and Karim (2005) developed a flood hazard map of the southwest region of Bangladesh, mainly covering the southwest coastal zone and found that a

Fig. 8.4 Storm surge destroying coastal area of Patengasea beach

major part of the area is moderately vulnerable to flood, with 26 % land categorized as highly vulnerable to flooding. Flood not only inundates the coastal land but also impacts the income of coastal people. Banerjee (2007) revealed that agricultural wages are dramatically declined in the area of severe flood and long time water stagnation.

8.3.5 Cyclone

Bay of Bengal (BOB), the biggest bay of the world, is surrounding by coastal zones of Bangladesh, India, Srilanka, and Myanmar, is a good breeding ground for cyclone. The bay generates 5 % of the world's tropical cyclone with very high impacts, representing 80 % of cyclone causalities of the world (Debsarma 2009). A quarter of the total cyclones generated in the BOB hit the coastal area of Bangladesh (Alam et al. 2003). Although cyclones are generally generated at 10°N or 10°S of the tropics, it becomes strong in shallow areas of continental shelf. Vast areas of Bangladesh EEZ is characterized by shallow shelf area of less than 100 m water depth, except a deep sea canyon SONG, located 30 km from the shoreline of Sundarban coast. Low shelf area, funnel-shaped coastal zone, elevated astronomical tides, and numerous coastal inlets create favourable condition to generate cyclone and storm surge (Fig. 8.4) along the coastal area of Bangladesh (Dube et al. 2009).

Islam and Peterson (2009) present an account of tropical cyclones on the Bangladesh coast over 127 years, for the period 1877–2003, and track a record of landfall cyclone of the period, with a conclusion that pre-monsoon (May–June) and post-monsoon (October–November) is peak season of cyclone when 70 % of total cyclone hit the coast. Bangladesh coast is highly vulnerable to cyclone and storm surges that show increasing trends in recent years (Fig. 8.5).

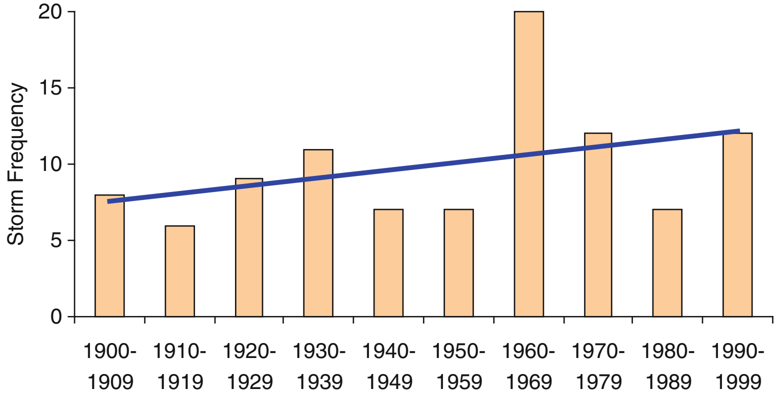


Fig. 8.5 Decadal frequency of landfall storm along Bangladesh Coast (data source: Islam and Peterson 2009)

Table 8.1 Coastal land and associated damage by cyclones

Sector	Damage type	1991 cyclone	Sidr (2007)	Aila (2009)
Crop land (ha)	Fully	47,673	120,000	31,357
	Partially	320,494	1,390,000	99,540
	Total	***368,167***	***510,000***	***130,897***
Embankment (km)	Fully	–	362	237
	Partially	–	1,928	1,557
	Total	***436***	***2,290***	***1,794***
Road (km)	Fully	–	1,714	2,233
	Partially	–	6,361	6,621
	Total	***2,350***	***8,075***	***8,854***
Reference		Karim (1995)	MoFDM (2008) GoB (2008)	UN (2010)

A total of 368,167 ha of crops were destroyed by the cyclone of 1991, resulting to a net loss of US$360 million in agricultural sector only. Crop loss by Cyclone Sidr and Cyclone Aila were 510,000 ha and 130,897 ha of agricultural land, respectively (Table 8.1). It is mentionable that this loss accounts for the immediate loss of agricultural production of coastal land and ultimate loss will be many-folds as the impacts of cyclone induced salinity intrusion will affect coastal lands for decades. Table 8.1 provides an account of the loss of crop land, embankments and rural road by 1991 cyclone Sidr and Aila, only on the coastal land of Bangladesh and its associated sector. A total of 19,670 ha of saltpan of Cox's Bazar district are under threat of washing by storm surge.

Cyclone has two types of effects on coastal land. First, it wipe-out all standing crops in the field converting productive land to a barren field all at a sudden. Second, the long-term impact of cyclone is the storm surges that could go as high as 9.1 m (Khalil 1993) of wave height with an outcome of the transportation of saline water into the coastal land resulting in salinization of coastal soil. Degradation of soil quality is long term impact of storm surge.

8.3.6 Salinity Intrusion

Coastal land of Bangladesh is highly affected by salinity intrusion because of its low elevation. Soil salinity of the coastal zone is increasing year after year and its expansion may be varied depending on the coastal zone. Soil salinity may exist in coastal soil of a few kilometres from the coastline that could widen up, as further as 180 km landward. In the wet season, coastal low land is directly inundated by saline water adding salt to soil. On the other hand, upward flow of underground saline water in the dry season raises soil salinity of the coastal zone (Haque 2006). A significant quantity of salt accumulates in the topsoil of the coastal region of Bangladesh by evaporation of soil moisture; particularly in the dry season of February to May; when agricultural fields are kept fallow and the longer period of fallowness enhances the harshness of salinity (Mondal et al. 2001). Rice production in the coastal zone is rainfall dependent in the rainy season, with additional low-saline river water irrigation in September to October. Coastal land is kept fallow during the rest of the time because of the high salinity.

The salinity level of coastal soil varies from region to region. Areas closer to the shoreline are more saline-prone than those further inland. About one-third of coastal soil is strongly saline. The area of saline soil rising as observed by the Soil Resources Development Institute (SRDI) that calculated the soil salinity of Noakhali, Jessore, Barisal and Barguna District which had increased by about 7 %, 11.5 %, 100 %, and 124.33 % respectively for the period 1970–2000 (Anonymous 2007). The increasing trend of soil salinity was also confirmed by Miah et al. (2007) indicating that saline soil of 52,000 ha in 1983–1984 attained to 203,000 ha in 2005–2006, pointing to a salinity increase of four times in the area during a time period of only 21 years.

Embankment construction was initiated in Pakistan period, before the independence of the country, along different flood prone area that was suggested by Krugg Mission in 1957 with a view to control flood waters. Polder Schemes and Coastal Embankment Project, Chandpur Irrigation project, and Muhuri River Project are among the larger flood control projects, those were implemented in the coastal zone of the country (Potten 1994; Alexander et al. 1998). However, flood control activities caused water logging in different parts of the coastal zone, when the embankments were flooded by extreme tidal surges; saline water was trapped inside the regulated area and became stagnant. The prolonged standing of saline water added salt to agricultural land turning it to saline soil. Thus flood control activities were a failure in attaining their goal and ironically increased the degree of flood devastation by increased surge heights and areas of saline water intrusion (Chowdhury and Karim 1998).

8.3.7 Land Transformation

Coastal agricultural land and mangrove forest have been converted to shrimp farm reducing the area of cultivable land. Shrimp farms are created both from agricultural land and forest land. Shrimp farming in Bangladesh was limited only around flood

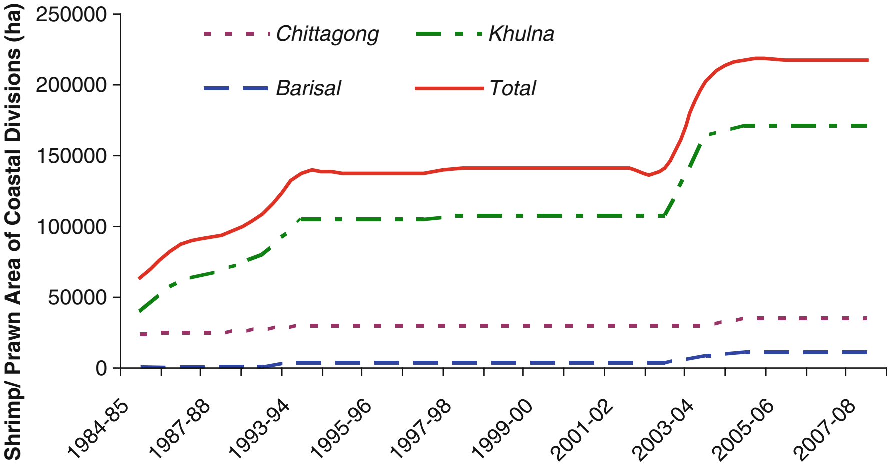


Fig. 8.6 Shrimp/Prawn Farm area of coastal divisions of Bangladesh (DoF 2009)

embankments early in the 1970s that was triggered in mid 1980s with a growing demand for shrimp in the world market (Ali 2003; Bala and Hossain 2009; Siddique and Volpe 2009), which is expressed in Fig. 8.6. As shrimp farming is more profitable than rice production, people started to convert rice fields to shrimp farms. Ninety percent of shrimp farming in Bangladesh is done by extensive method (Siddique and Volpe 2009) where shrimp is produced by minimum input of food and nutrients and requires more land, compared to the semi-intensive or the intensive method where. To capture more area under shrimp cultivation, agricultural land and coastal mangrove forest are prepared for shrimp farm both legally and illegally.

A study land cover change study by Ali (2006) in Damarpota Village in Khulna worked out that 274 ha of agricultural land, which is 79 % of principal rice field of the village, was converted to shrimp farms during the 18 years from 1985 to 2003. Conversion of coastal land into shrimp farms not only limits the agricultural land, but also degrades the soil quality of the agricultural land. Continuous shrimp farming in the same land results in an increase of soil salinity and acidity; with a reduction of soil nutrients, including calcium, potassium, magnesium, and organic carbon (Ali 2006). The present rate of conversion of coastal land into shrimp pond is increasing at a rate of 0.5 % per year. The rate is also alarming for salt bed conversion, which is growing at a rate of 18 % per year (Iftekhar 2006).

Land transformation was also observed along the eastern part of the coastal zone. A news report by Chowdhury (2009), referring district agriculture office bring up that farmer used to cultivate rice in 11,036 ha of land in Teknaf Upazilla of Cox's Bazar District during the period 2004–2005; of which 2,800 ha was used to cultivate Boro in summer season. During the year 2008–2009, the rice cultivation area was only 863 ha, resulting transformation of rice field of about 2,000 ha into salt-bed in a short period of 4 years.

In addition to land use change, it is used in improper way that limits the productivity of coastal land. A study by Hossain and Lin (undated) mapped land suitability for shrimp farms, salt beds, and mangrove plantation area of Cox' Bazar of the southeast coastal zone with a conclusion that most of the existing land use was in an overlap of the fitness. Furthermore, there are growing user conflicts between multi stake land users (Hossain et al. 2003). In addition to the mentioned vulnerability, droughts and earthquake add extra vulnerability to coastal land of the country. Moreover, landslides are reported in the coastal zone mainly in Chittagong urban area and mainly prompted by hill cutting of coastal areas of Chittagong and Cox's Bazar districts.

8.4 Discussion

The coastal land of Bangladesh is vulnerable to flooding, erosion, salinity intrusion, and cyclonic hazards. As the country is the most densely populated country in the world, it is a difficult task to relocate population community to further landward. To adjust the situation, Bangladesh needs to develop a strategy to protect its coastal population. All the foreseen impacts of coastal land will affect the agriculture sector of the coastal zone, threatening food security of the country, as agricultural production is the basis of the economy of the country.

Rise in sea level is a potential long-term threat to the coastal land of the country. Most of the studies predict an inundation of 17–20 % of coastal land by 1 m sea level rise within a time frame of 100 years. In spite of a great concern of SLR affect in Bangladesh, there is a handful studies concentrated on exploring SLR in the country. Sea-level rise is one of the significant outcomes of global warming where Bangladesh has a little role to play to stop it. However, there is scope of local level management to deal with the situation. About one-third of the present sediment load influx into the coastal zone is capable in keeping pace with the present rate of sea-level rise of the zone (Khalequzzaman 1989) which in under interruption by the embankment building. A normal flow of coastal river water and sediment deposition from it would have keep pace with the local sea level rise.

The exact rate of subsidence in the coastal land of the country is yet unknown. However, it is obvious that the rate is high in the area, and is exacerbating the rate of local sea-level rise. Potential role of subsidence in accelerating SLR will aggravate the sea-level rise impacts on the country. To adjust with the situation, subsidence needs to be considered in management process. For a better understanding of local subsidence, an in-depth geologic, geomorphologic, and sub-surface survey is in priority list where coastal managers need to pay their attention.

The south-central coast is very unstable and the change is visible even for short period of 1 year. Erosion is observed mainly on the northern part of the coastal islands and accretion at the southern part, forming new lands on the southern side. This new lands are unstable because of less compactness and bonding and can be protected from further erosion by creating new mangrove forest (Hossain 2001). It is mandatory by existing rule of Bangladesh that any new land accreted (locally known as *Char* land) should go under the jurisdiction of the ministry of forest for a 20 year time period to plant mangrove forest for the attaining of soil maturity (Iftekhar and Islam 2004). After the defined time frame the land ownership goes to the ministry of land. But the rules are not strictly followed because of poor enforcement and rural influential people grab the land planted by the forest department. Thus Forest department cannot hold the land for 20 years and is unable to handover it to the ministry of land resulting the ownership to local peoples who cut the plants of the forest department. Deforested new land soon cannot accomplish maturity and end up with erosion. The implementation of the mentioned rule need to be effective to ensure that accreted land can reach to its development.

Flood causes great loss to the life and livelihood. Coastal flooding, including flush flood needs due attention to protect coastal land from water stagnation and water logging. Although flood is proven to be a great disaster in different part of the world, it is treated as a soil recharge agent and compensation of sediment loss due to sheet erosion, under normal circumstances (Karim 1995). Very often, flood protection activities in Bangladesh become a flood causing factor. The reason behind this is inappropriate steps for flood control activities (Khalequzzaman 1992; Choudhury et al. 2004). To control flood, Bangladesh executed engineering approach cordoning the flood vulnerable area as a protection measure of flood flow without due consideration of some alternative possibilities like heavy rain that could overflow the cordoned area, or storm surge that could destroy the polder by its high energy waves. Rain or surge water trapped inside the embankment results water stagnation as rain water does not get any way out. In case of embankment failure, narrow outlet discharge little water compare to the net storage inside the embankment wall resulting prolong time for a full evacuation of trapped water. Engineering solution to natural process boosted up the magnitude of the problem. Long time standing water resulted in degraded soil quality leading to decreased productivity of coastal land, and the final output was a decline in agricultural production. Flooding contributed to decreased production by damaging crops in the flooding year and by depreciated soil nutrients in the subsequent years. Indiscriminate polder construction to protect agricultural land from flood may not be a feasible solution for the coastal zone of Bangladesh, especially for the Sundarbans coastal area that needs an intensive fresh–marine interface for the survival of the ecosystem.

Cyclone induced vulnerability of coastal land is associated with the destruction of standing crops and a decrease of long-term fertility of the land. A single cyclone, as it was in 1970 or in 1991 could ravage the coastal zone stressing the national economy. Cyclone shows seasonal variation reaching peak in pre and post monsoon season, with highest hit in October, with regional variation hitting highest in Khulna and Barisal coast (Islam and Peterson 2009). Coastal landuse needs to be designed with seasonal and geographic behaviour of cyclone. Paradoxically, death toll from cyclone in Khulna coast was lower than Barisal Noakhali or Chittagong Coast even though it received highest number of cyclone (31 %) in the last century.

The presence of the Sundarbans along Khulna Coastal zone safeguarded the area motivating that coastal mangrove forest could provide defence for other coastal area from the natural hazard. Creating mangrove forest on newly accreted coastal land will protect the area from cyclone affects (Umitsu 1997) and will help in stabilizing soft coastal soil.

A study by Allison (1998) showed erosion in the Sundarban coast with an indication of tidal water domination in the area that is dominating in salinity intrusion in the southwest coastal zone as the influences of tidal water contribute in salinization process in a coastal plain. Salinity intrusion imposes high threat to the biodiversity of the Sundarban and also to coastal agriculture and fisheries. Factors influencing salinity intrusion need to be addressed foremost and integrated in the development policies. Coastal management activities, including embankment building deserve in-details impacts studies to minimize its adverse impacts and also for a long term sustainability. In addition to minimize salinity intrusion, provision of adaptation strategy needs to be kept in mind. Introduction of salinity tolerant species for agricultural and fisheries sectors is a way of attention for coastal farmers. In such a case, there must be an obligation of extensive research for the investigation of potential impacts of the species to be introduced into the environment.

Land transformation, especially conversion of mangrove to shrimp field was a mentionable result of wrong development policy of the state. Development strategy without proper environmental impact assessment, through a target of financial benefit only, turned productive land into unproductive barren field of saline soil. A possible way out from saline soil is to irrigate land with rain water. Farmers are not interested to cultivate fields of saline soil by the irrigation of rain water because of low harvest at the end. Government need to support farmers with incentives to cultivate such saline field and thus help desalinization of the land in long run. Donor agencies who were mastermind in developing shrimp cultivation in Bangladesh should support the country in incentive stimulation. In addition, encroachment of coastal land should be ruled strictly.

Generally, vulnerability is strongly related to population. From climate change perspective, Intergovernmental Panel on Climate Change (IPCC) outlines,

> Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC 2007).

However, all vulnerabilities have two aspects: biophysical and socio-economic (Szlafsztein and Sterr 2007). Understanding physical vulnerability is the fundamental ground for a better portrait of socio-economic vulnerability. The capacity of a community may alter the vulnerability extent of a system. Community with higher capacity is less vulnerable than a weak community. Nevertheless, community statuses do not necessarily influence the physical vulnerability of a system itself. This study has documented the physical vulnerability of coastal land of Bangladesh. Superimposing coastal population will generate a more sensible vulnerability picture of the coast.

8.5 Recommendation

Having significant coastal zone with low elevation, the country is highly vulnerable to sea-level rise. But a scientific investigation of SLR along the coastal zone of Bangladesh is yet to be done with focus on other physical factors such as land subsidence, sedimentation, sediment compaction and relevant tectonic dimensions. A thorough study of SLR and its associated impacts are essential to understand detailed coastal vulnerabilities of coastal land. It is a challenging task both from the technical and the financial point of view. Assessing the rate of local subsidence will contribute to come up with a more realistic scenario. The country needs collaboration with international experts of the field, along with ground trothing of the scientific investigation reports, promotion of local knowledge, for a better understanding of sea-level change related facts and figures.

Coastal land of Bangladesh is under tremendous pressure from multi-hazard threats. A single adverse climatic event can damage coastal lands with full destruction of standing crops. Keeping provision of disaster mitigation insurance (Atmanand 2003; Kunreuther 2006; Picard 2008; Ye et al. 2008) could be possible solution to back up coastal land users during their crisis period. Some parts of the zone are covered by trees that were planted under Green Belt Project, offering a protection to cyclone and storm surges. The coastal areas left without green belt need to be brought under plantation to have a first order defence against surge event.

Erosion and accretion are two sides of coin in the south central coast where coast line change occurs dramatically. A close observation of the Meghna River Estuary and tidal rivers of the Sundarbans are needed to understand in-details of erosion accretion patterns of south-central and southwest coastal area. Although it is difficult to have an accurate forecast of changing pattern of a coast, but understanding its long-time behaviour by historical image analysis will be able to indicate its shifting boundary in the zone, such knowledge will be very useful in future land use plan.

Coastal land use zoning is important to obtain optimum productivity from same area of land. Suitability of coastal land use needs to be identified to avoid land use conflicts. Seasonal sharing of coastal land will also maximize its use potentials and extensive use in cyclone free period will reduce damage from cyclone and flood.

Agricultural land transforming to salt bed is one way of using land, and once transformed cannot be converted to agricultural land again. Continuous transforming of agricultural land will decrease the rice production, resulting food insecurity of the country. It is a vital need to stop the conversion of agricultural land into salt bed. It is worthwhile to mention that salt is an important sector from political point of view and leaders are not interested to interact with the sector indicating that authority might neglect the action of such conversion. The vital point to stop salt bed conversion is that the country produces about 0.4 million ton of surplus salt in every production season (Taher 2009) indicating its self-reliance in the sector. A vast area of coastal mangrove, especially southeast and southwest zone is deforested resulting change in ecosystem of the area. Desalinization (Smedema and Jenkins 1988) of newly salined area will protect further intrusion of soil salinity.

Deforestation of coastal mangroves and transformation of coastal land need to be stopped by legal implementation.

Soil Resources Development Institute of Bangladesh Government develops soil map for upazillas of Bangladesh, which is published irregularly. The soil map of the coastal zone needs to produce regularly and even a local level map will be helpful in decision making of coastal land use. To protect further salinization of the area, supply of freshwater should be ensured. There are 54 transnational rivers that flow into Bangladesh from India and water from many of them was diverted in the upper country by barrage building, including the Farrakka having a consequence of decreased freshwater flow. Bangladesh needs to improve its environmental diplomacy to convince this neighbouring country for the achievement of a higher freshwater supply from upstream. In addition, feasibility of salinity tolerate species should be tested both for agriculture and fisheries sector, and if any suitable species found which is friendly to environment, ecosystem, agriculture and fisheries of the zone, could be introduced to cope with the changing environment.

A good assessment of vulnerability needs historical data that is not properly collected in Bangladesh. A few efforts exist to collect data, which are irregular and poorly maintained, and inaccessible by researchers in the end. Development of a coastal database and easy access by researchers to it will facilitate quality research in the sector, and output of that will be a good instrument for coastal managers of the zone. Data set for individual disaster is essential for a better understanding of the vulnerabilities.

8.6 Conclusion

The coastal land of Bangladesh is under potential threat of multi-hazard vulnerabilities. The land area of the coastal zone is extremely vulnerable to sea-level rise, flood, cyclone, storm-surge, subsidence, salinity intrusion and coastal erosion. In addition to these environmental hazards and natural disaster, fresh water eco-system is under conversion into brackish and saline system which is subsequently putting stress on agriculture in the zone as land transformation from crop to other use are evident. Engineering solution such as embankment, dykes, polder building without proper environmental impact assessment is a potential threat to the coastal eco-system in the long run. Geomorphology of the coastal area is in formative stage and such flood protection stops sedimentation and land formation process. The state needs to prepare early enough to adjust with upcoming impacts, for the protection of its large number of coastal population. Afforestation and reforestation of mangrove and suitable forest species also contribute to vulnerability reduction and enhance resilience in the coastal area. Coastal social and economic as well as physical infrastructures could be brought under climate and disaster resilient development planning and budgeting framework. Climate and disaster risk transfer such as insurance policy will help stakeholders of coastal people, community and multi-purpose business on land. Eco-system based adaptation and disaster risk reduction initiatives in the policy and planning will facilitate a better management of the coastal land and environment. Formulation of coastal vulnerability index including damage and loss assessment as a basis for planning and resource allocation for comprehensive development should get priority attention towards enhancing resilience through vulnerability reduction approach.

Acknowledgements This paper was enriched by receiving comments and inputs from Professor Colin Woodroffe. However, any mistake remains with us.

References

Alam MM, Hossain MA, Shafee S (2003) Frequency of Bay of Bengal cyclonic storms and depressions crossing different coastal zones. Int J Climatol 23(9):1119–1125

Alexander MJ, Rashid MS, Shamsuddin SD, Alam MS (1998) Flood control, drainage and irrigation projects in Bangladesh and their impact on soils: an empirical study. Land Degrad Dev 9(3):233–246

Ali A (1996) Vulnerability of Bangladesh to climate change and sea level rise through tropical cyclones and storm surges. Water Air Soil Pollut 92(1):171–179

Ali A (2000) Vulnerability of Bangladesh coastal region to climate change with adaptation option. Bangladesh Space Research and Remote Sensing Organization (SPARRSO), Dhaka

Ali AMS (2003) Farmers' knowledge of soils and the sustainability of agriculture in a saline water ecosystem in Southwestern Bangladesh. Geoderma 111(3–4):333–353

Ali AMS (2006) Rice to shrimp: land use/land cover changes and soil degradation in southwestern Bangladesh. Land Use Policy 23(4):421–435

Ali AMS (2007) September 2004 flood event in southwestern Bangladesh: a study of its nature, causes, and human perception and adjustments to a new hazard. Nat Hazards 40(1):89–111

Allison MA (1998) Historical changes in the Ganges-Brahmaputra delta front. J Coast Res 14(4):1269–1275

Allison MA, Kepple EB (2001) Modern sediment supply to the lower delta plain of the Ganges-Brahmaputra River in Bangladesh. Geo-Mar Lett 21(2):66–74

Anonymous (2007) Bangladesh coasts face increased salinity. The Financial Express, Dhaka, p XVI (05 Dec 2007)

Atmanand (2003) Insurance and disaster management: the Indian context. Disaster Prevent Manag 12(4):286–304

Bala BK, Hossain MA (2009) Integrated management of coastal zone for food security. Department of Farm Power and Machinery, Bangladesh Agricultural University, Dhaka, p 134

Banerjee L (2007) Flood disasters and agricultural wages in Bangladesh. Dev Change 38(4):641–664

Begum S, Fleming G (1997) Climate change and sea level rise in Bangladesh. Part II: Effects. Mar Geodesy 20(1):55–68

Blasco F, Aizpuru M, Gers C (2001) Depletion of the mangroves of Continental Asia. Wetlands Ecol Manag 9(3):255–266

Boak EH, Turner IL (2005) Shoreline definition and detection: a review. J Coast Res 21(4):688–703

Choudhury AM, Haque MA, Quadir DA (1997) Consequences of global warming and sea level rise in Bangladesh. Mar Geodesy 20(1):13–31

Choudhury NY, Paul A, Paul BK (2004) Impact of costal embankment on the flash flood in Bangladesh: a case study. Appl Geogr 24(3):241–258

Chowdhury FK (2009) Rice field decreasing in Teknaf: increasing salt bed (Teknafe Komse Dhanijomi: Barse Laban Chash). The Daily Jai Jai Din, Dhaka (Last page)

Chowdhury JU, Karim MF (1998) A risk-based zoning of storm surge prone area of the Ganges Tidal Plain. J Civil Eng CE-24(2):221–233

Coleman JM, Huh OK, Braud D (2008) Wetland loss in world deltas. J Coast Res 24(sp 1):1–14

Debsarma SK (2009) Simulations of storm surges in the Bay of Bengal. Mar Geodesy 32(2):178–198

DoF (2009) Fisheries Statistical Yearbook of Bangladesh (2007–2008), Department of Fisheries, Ministry of Fisheries and Livestock, Dhaka, Bangladesh

Dube SK, Jain I, Rao AD, Murty TS (2009) Storm surge modelling for the Bay of Bengal and Arabian Sea. Nat Hazards 51(1):3–27

Ghosh T, Bhandari G, Hazra S (2001) Assessment of landuse/landcover dynamics and shoreline changes of Sagar Island through remote sensing. In: The 22nd Asian conference on remote sensing, Centre for Remote Imaging, Sensing and Processing (CRISP), National University of Singapore, Singapore

GoB (2008) Cyclone Sidr in Bangladesh: Damage, Loss and Needs Assessment for Disaster Recovery and Reconstruction, Economic Relations Division MoF, Report prepared by the Government of Bangladesh (GoB) and assisted by the International Development Community with Financial Support from the European Commission

Goodbred SL, Kuehl SA (1998) Floodplain processes in the Bengal Basin and the storage of Ganges-Brahmaputra river sediment: an accretion study using ^{137}Cs and ^{210}Pb geochronology. Sedim Geol 121(3–4):239–258

Haque SA (2006) Salinity problems and crop production in coastal regions of Bangladesh. Pakistan J Bot 38(5):1359–1365

Hoque M, Alam M (1997) Subsidence in the lower deltaic areas of Bangladesh. Mar Geodesy 20(1):105–120

Hossain MS (2001) Biological aspects of the coastal and marine environment of Bangladesh. Ocean Coastal Manag 44(3–4):261–282

Hossain MS, Lin CK (undated) Land suitability analysis for integrated coastal zone management in Cox's Bazar. A Remote Sensing and GIS Approach, Integrated Tropical Coastal Zone Management, Asian Institute of Technology, Bangladesh/Thailand

Hossain MS, Lin CK, Hussain MZ (2003) Remote sensing and GIS applications for suitable mangrove afforestation area selection in the coastal zone of Bangladesh. Geocarto Int 18(1): 61–65

Iftekhar MS (2006) Conservation and management of the Bangladesh coastal ecosystem: overview of an integrated approach. Nat Resour Forum 30(3):230–237

Iftekhar M, Islam M (2004) Managing mangroves in Bangladesh: a strategy analysis. J Coast Conserv 10(1):139–146

IPCC (2007) Climate change 2007: impacts, adaptation and vulnerability, summary for policymakers. Intergovernmental Panel on Climate Change (IPCC)

Islam MR (2006) Managing diverse land uses in coastal Bangladesh: institutional approaches. In: Hoanh CT, Tuong TP, Gowing JW, Hardy B (eds) Environment and livelihoods in tropical coastal zones. CAB Int 237–248

Islam T, Peterson RE (2009) Climatology of landfalling tropical cyclones in Bangladesh 1877–2003. Nat Hazards 48:115–135

Islam MM, Sado K (2000) Flood hazard assessment in Bangladesh using NOAA AVHRR data with geographical information system. Hydrol Process 14(3):605–620

Islam MJ, Alam MS, Elahi KM (1997) Remote sensing for change detection in the Sunderbands, Bangladesh. Geocarto Int 12(3):91–100

Karim N (1995) Disasters in Bangladesh. Nat Hazards 11(3):247–258

Karim MF, Mimura N (2008) Impacts of climate change and sea-level rise on cyclonic storm surge floods in Bangladesh. Glob Environ Chang 18(3):490–500

Khandker H (1997) Mean sea level in Bangladesh, Marine Geodesy 20(1):69–76

Khalequzzaman M (1989) Environmental hazards in the coastal areas of Bangladesh. In: Ferreras S, Pararas-Caryannis G (eds) Natural and man-made coastal hazards. Ensenada, Mexico/ Sandiego, pp 37–42

Khalequzzaman M (1992) Feasibility of the flood control megaproject in Bangladesh. Int J Environ Educ Inform 11(1)
Khalil GM (1992) Cyclones and storm surges in Bangladesh: some mitigative measures. Nat Hazards 6(1):11–24
Khalil GM (1993) The catastrophic cyclone of April 1991: its impact on the economy of Bangladesh. Nat Hazards 8(3):263–281
Khan TMA, Singh OP, Rahman MS (2000) Recent sea level and sea surface temperature trends along the Bangladesh coast in relation to the frequency of intense cyclones. Mar Geodesy 23:103–116
Khan MSH, Parkash B, Kumar S (2005) Soil-landform development of a part of the fold belt along the eastern coast of Bangladesh. Geomorphology 71(3–4):310–327
Kumar PKD, Gopinath G, Laluraj CM, Seralathan P, Mitra D (2007) Change detection studies of Sagar Island, India, using Indian remote sensing satellite 1C linear imaging self-scan sensor III data. J Coast Res 23(6):1498–1502
Kunreuther H (2006) Disaster mitigation and insurance: learning from Katrina. Ann Am Acad Polit Soc Sci 604(1):208–227
McGranahan G, Balk D, Anderson B (2007) The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. Environ Urban 19(1):17–37
Miah MG, Bari MN, Ahamed T, Saha U (2007) Agriculture in the fragile environment of Bangladesh: looking into the future, Retrieved March 30, 2013, from http://www.academia.edu/2494461/Agriculture_in_the_Fragile_Environment_of_Bangladesh_Looking_into_the_Future
Mikhailov VN, Dotsenko MA (2007) Processes of delta formation in the mouth area of the Ganges and Brahmaputra Rivers. Water Resour 34(4):385–400
Milliman JD, Broadus JM, Gable F (1989) Environmental and economic implications of rising sea level and subsiding deltas: the Nile and Bengal examples. Ambio 18:340–345
Mirza MMQ, Warrick RA, Ericksen NJ, Kenny GJ (2001) Are floods getting worse in the Ganges, Brahmaputra and Meghna basins? Glob Environ Change B Environ Hazards 3(2):37–48
MoFDM (2008) Super Cyclone SIDR 2007: Impacts and Strategies for Interventions, Ministry of Food and Disaster Management, Bangladesh Secretariat, Dhaka, Bangladesh
Mondal MK, Bhuiyan SI, Franco DT (2001) Soil salinity reduction and prediction of salt dynamics in the coastal ricelands of Bangladesh. Agric Water Manag 47(1):9–23
Morgan JP, McIntire WG (1959) Quaternary geology of the Bengal Basin: East Pakistan and India. Bull Geol Soc Am 70:319–342
MoWR (2003) Minutes of the 6th meeting of the Inter-ministerial Technical Committee for the Integrated Coastal Zone Management Plan (ICZM) Project. Ministry of Water Resources, Dhaka
Mukherjee D (2007) Evolution of the coastline of West Bengal during 20th century. PhD, Department of Geography, University of Burdwan, India
Mustafi BAA, Azad MAS (2003) The 1998 flood: losses and damages of agricultural production in Bangladesh. J Biol Sci 3(2):147–156
Nicholls RJ, Goodbred SL (2004) Towards integrated assessment of the Ganges-Brahmaputra delta. In: Proceedings of 5th international conference on Asian marine geology and 1st annual meeting of IGCP475 DeltaMAP and APN Mega-Deltas
Ortiz CAC (1994) Sea-level rise and its impact on Bangladesh. Ocean Coast Manag 23(3):249–270
Paul BK, Rasid H (1993) Flood damage to rice crop in Bangladesh. Geogr Rev 83(2):150–159
Picard P (2008) Natural disaster insurance and the equity-efficiency trade-off. J Risk Insur 75(1):17–38
Potten D (1994) The impact of flood control in Bangladesh. Asian Affairs 25(2):156–162
Sarwar GM, Khan MH (2007) Sea level rise: a threat to the coast of Bangladesh. Int Forum Int Q Asian Stud 38(3/4):375–397
Siddique MAL, Volpe JP (2009) Eco-friendly sustainable shrimp aquaculture in Bangladesh: minimizing coastal degradation. In: Erlend Moksness ED, Stottrup J (eds) Integrated coastal zone management. Blackwell, West Sussex, pp 116–130

Singh OP (2002) Spatial variation of sea level trend along the Bangladesh Coast. Mar Geodesy 25(3):205–212

Smedema LK, Jenkins A (1988) Desalinisation of recently accreted coastal land in the eastern part of the Bay of Bengal, Bangladesh. Agric Water Manag 13(1):1–11

Stanley DJ, Hait AK (2000) Holocene depositional patterns, neotectonics and Sundarban mangroves in the western Ganges-Brahmaputra delta. J Coast Res 16(1):26–39

Stoddart DR, Pethick JS (1984) Environmental hazard and coastal reclamation: problems and prospects in Bangladesh. In: Bayliss-Smith TP, Wanmali S (eds) Understanding green revolutions: agrarian change and development planning in South Asia. Cambridge University Press, Cambridge, pp 338–361

Szlafsztein C, Sterr H (2007) A GIS-based vulnerability assessment of coastal natural hazards, state of Pará, Brazil. J Coast Conserv 11(1):53–66

Taher F (2009) Conspiracy to ruin salt industry (In Bengali: Laban ShilpaDhongsherChockranto). Tha Daily Suprobhat Bangladesh, Chittagong

Tingsanchali T, Karim MF (2005) Flood hazard and risk analysis in the southwest region of Bangladesh. Hydrol Process 19(10):2055–2069

Uddin AMK, Kaudstaal R (2003) Delineation of the coastal zone. Program Development Office for Integrated Coastal Zone Management Plant (PDO-ICZMP), Dhaka, pp 1–42

Umitsu M (1993) Late Quaternary sedimentary environments and landforms in the Ganges Delta. Sedim Geol 83(3–4):177–186

Umitsu M (1997) Landforms and floods in the Ganges delta and coastal lowland of Bangladesh. Mar Geodesy 20(1):77–87

UN (2010) Cyclone Aila, Joint UN Multi-sector Assessment and Response Framework, Dhaka, June 2010

Woodroffe CD, Nicholls RJ, Saito Y, Chen Z, Goodbred SL (2006) Landscape variability and the response of Asian megadeltas to environmental change: the Asia-Pacific Region. In: Harvey N (ed) Global change and integrated coastal management. Springer, Dordrecht, pp 277–314

World Bank (2000) Bangladesh: climate change & sustainable development. World Bank, Dhaka

Worm HU, Ahmed AMM, Ahmed NU, Islam HO, Huq MM, Hambach U, Lietz J (1998) Large sedimentation rate in the Bengal delta: magnetostratigraphic dating of Cenozoic sediments from northeastern Bangladesh. Geology 26(6):487–490

Ye T, Yokomatsu M, Okada N (2008) Combined international and intergenerational disaster risk diversification: an innovative instrument for government intervention into the private disaster insurance program. In: 2008 I.E. international conference on systems, man and cybernetics, pp 2887–2894

Chapter 9
Equity and Justice Issues for Climate Change Adaptation in Water Resource Sector

Shamsun N. Ahmed and Aminul Islam

Abstract Equity and justice concerns are the emerging challenges for adaptation as the new and agreed research agenda for sustainable solution to the range of issues surrounding global climate change in general and water resource management in particular. This chapter focuses on implications of policy, programming and budgeting for climate change adaptation measures in water sector and subsequent potential impact on social, economic and environmental and risk management parameters and differential access to its benefit to different social strata. It is deemed necessary to determine the direction, trend and magnitude of the cost of adaptation and the differential ability to undertake adaptive initiative. An analysis is made on lessons learned about the similarities of disaster risk reduction and climate change adaptation in water sector related to social, economic and environmental aspects involved with reference to Bangladesh. Research on the political economy of climate change impact on water sector being a cross-cutting issue demonstrate that there will always be winners and losers from the extreme events. A number of evidences shared in this chapter with reference to water and flood management in Bangladesh, which may help in judgement for decision making on adaptation with equity and justice considerations. Climate change is posing serious threat to poor's access to common pool resources as there is no legal instrument to ensure their right on either water resource or even dead channel. Recent studies indicate that Gangetri glacier in the Himalaya that feeds the Ganges and Jamuna rivers system will be exhausted by 2035, which will affect the quality and productivity of the water resources in the sub-continent. The wetlands will be fragmented and disconnected from the main river system. Since coastal Bangladesh is geomorphologically at the formative stage, therefore, structural solutions, such as the building of embankments along the

---

S.N. Ahmed
Department of Economics, Dhaka University, Dhaka, Bangladesh

A. Islam (✉)
United Nations Development Programme, Dhaka, Bangladesh
e-mail: aminul.islam@undp.org

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*, Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_9, © Springer Japan 2013

rivers and polders in the coastal regions in Bangladesh, needs careful examination and multi-stakeholder consensus on environmental, hydrologic such as tidal river dynamics, economic, social and ecological consequences. Approach to water resource management issues in Bangladesh in the face of emerging climate change scenario is a complex challenge but would be effective and sustainable provided watershed-management principle in bigger geographic scale is to be followed to address the issues of ecosystem based adaptation with a network of participatory interactive approach of management. Water resource development with equity and justice framework could be mainstreamed through good governance in agriculture, forestry, river management and urbanization, flood forecasting, water retention and regional cooperation.

Keywords Climate change adaptation • Climate justice • Equity • Poverty and vulnerability • Water resources

9.1 Climate Vulnerability: Water Sector Context

9.1.1 Climate Change Implications on Ganges, Brahmaputra, and Meghna (GBM) River Basin

Vulnerability to climate change context, Bangladesh is one of the most critical countries in the world to climate risks. Two-thirds of the landscape and people of the country as well are existing less than 5 m above sea level and are susceptible to river and rainwater flooding, particularly during the monsoon. Due to its location at the tail end of the delta formed by the Ganges, Brahmaputra, and Meghna (GBM) rivers, the timing, location, and extent of flooding depends on the precipitation in the entire GBM basin, not just on the 7 % of the basin that lies within the country. Nearly 80 % of the country's annual precipitation occurs during the summer monsoon season, when these rivers have a combined peak flow of 180,000 m^3/s, the second highest in the world. Once in every 3–5 years, up to two-thirds of Bangladesh is inundated by floods that cause substantial damage to infrastructure, housing, agriculture, and livelihoods. Low-lying coastal areas are also at risk from tidal floods and severe cyclones. In the face of emerging climate change scenario, on an average once in every 3 years, a severe cyclone makes landfall on the Bangladesh coastline (traditional return period once in 20 years), either before or after the monsoon. The largest damages from a cyclone result from the induced-storm surges, sometimes in excess of 10 m which is increasing in height over time as evidences are currently noticed.[1]

[1] UNDP/MoEF implemented Community based coastal adaptation to climate change through afforestation projects reveals fact that tidal wave over the last 3 years has increased as the baseline dyke height erected by the project beneficiaries are found to be overtopped in Kukri-Mukri, Bhola, Barguna and Hatiya sites in recent years.

9.1.2 Climate Change Influence on Flash Flood and Drought

Two determining change factors for variability in climatic elements are the rise in temperature and a change in the precipitation regime. These variations of climatic elements has wide ranging implications to water sector which has cross-cutting implications as it give rise to changes in the human systems of agriculture, industry, energy, infrastructure, health, livelihood as well as disaster. In Bangladesh flash floods generally occurs in the north-east, south-east and Chittagong region. But devastating and extended flash flood is a recurrent phenomenon for the north-east region of Bangladesh. Flash floods normally occur between mid-April to end April. Recently this trend has been changing and local people reported that in recent years flash floods have been coming earlier than usual. Figure 9.1 shows changed flooded area due to climate change in Bangladesh which has further socio-economic implications. Now the question is how strategic policy decisions and adaptation programme intervention can address the equity and justice concerns while designing the programme.

Droughts are a recurrent feature in Bangladesh. The droughts occurring in Bangladesh are not meteorological droughts but merely agricultural droughts which could be also termed as severe moisture stress. Generally, two critical dry periods are notable in Bangladesh (Karim et al. 1990). Rabi and pre-Kharif drought (January/May), due to: (a) the cumulative effect of dry days; (b) higher temperatures during pre-Kharif (>400 °C in March/May); and (c) low soil moisture availability. The drought affects all Rabi crops, such as HYV Boro, Aus, wheat, pulses and potatoes especially where irrigation possibilities are limited. Drought affects sugarcane production. It also affects fruit trees, such as jackfruit, litchi, and banana, which often die during this period. But the loss of rice production is the most costly damage incurred through droughts in Bangladesh.

Kharif drought from June/July to October, created by sub-humid and dry conditions in the highland and medium highland areas of the country (in addition to the west/northwest; the Madhupur tract in the central parts of the country is also drought prone). Shortage of rainfall affects the critical reproductive stages of transplanted Aman rice crops in December, reducing yield, particularly in those areas with low soil moisture holding capacity. With the increase in global temperature, this trend will has further aggravating impacts on dry season agriculture.

Water is so central to the lives of rural communities in Bangladesh that anything that affects these resources has livelihood implications. Bangladesh is a country where agricultural production is the mainstay of the rural communities' livelihood system, and therefore livelihood strategies are inextricably linked to the nation's water resources management. Management of water resources has critical implications for people's lives and livelihoods for overall economic development and for social prosperity. Social theories of justice, equity and fairness underscore the need for ensuring social justice in water resource management (Syme et al. 1999; Tisdell 2003). The equity concept implies protection of water rights and access to safe drinking water, which is a basic human need. According to Phansalkar (2007), equity in access to and use of water and the distribution of the impacts of water

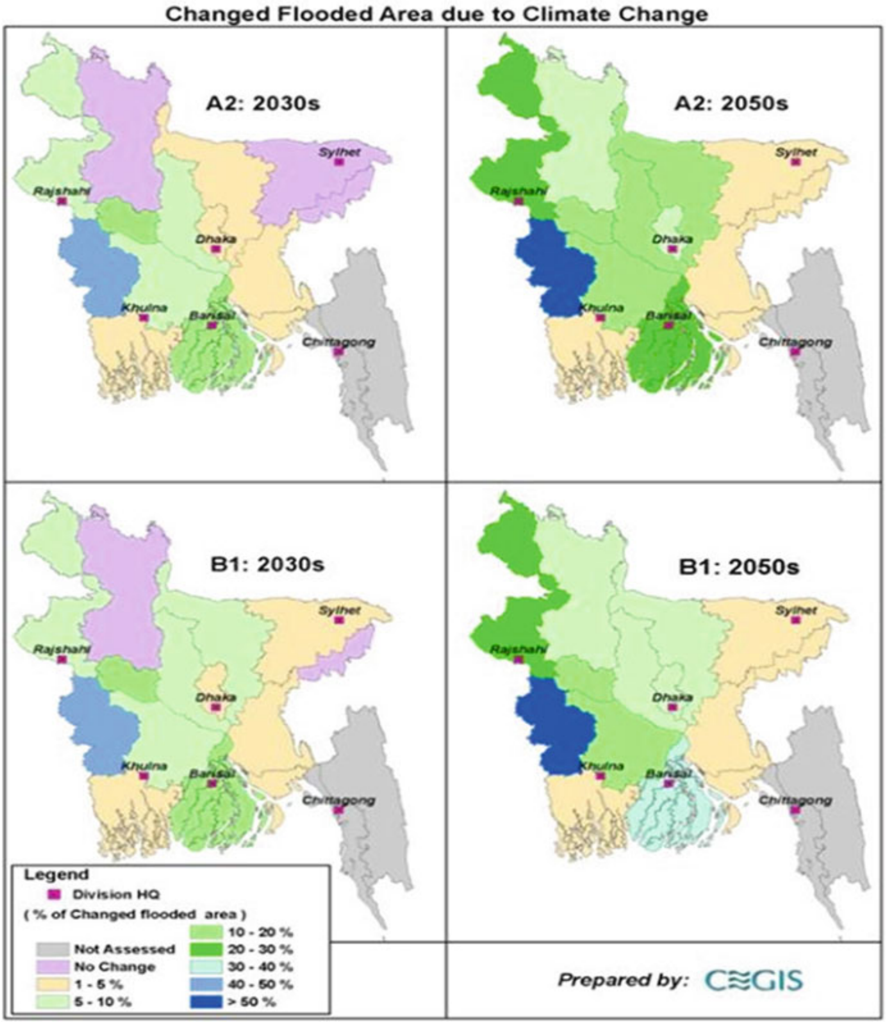


Fig. 9.1 Changes in flooded area in Bangladesh in 2030s and 2050s

resource development intervention have four elements: (1) Social equity: equity between different groups of people living in the same location. (2) Spatial equity: equity between people living in different regions (Saleth and Dinar 2004). (3) Gender equity: equity between men and women in sharing labour costs, efforts to access and use water, and its benefits. (4) Inter-generational equity: equity in enjoyment of natural resources, including water across generations of people (Divan and Rosencranz 2005).

The focus of water sector activities has been on coastal embankment, flood control, drainage and irrigation to support the agriculture sector. As a result, the role of water in other sectors, such as domestic water supply and sanitation, fisheries, navigation, industrial uses, hydropower, ecology and nature and disaster management, has mostly been neglected (Ahmad 2003). However, the 1999 National Water Policy (NWP) recognized for the first time the role of water in poverty alleviation and called for inclusive water management, taking into consideration the national goal of poverty alleviation, amongst others (Ministry of Water Resources 1999). The policy was further revised in 2000 and approved by the government. To facilitate the implementation of the NWP, the government approved a 25-year National Water Management Plan (NWMP) in 2004. The plan provides guidelines to develop programmes for better management of water resources in the country. The main elements of the NWMP include the multi-use approach to water (not just flood protection but also irrigation, drinking water and other uses) and an emphasis on "soft" approaches, such as better management of water resources, instead of just hard engineering approaches.[2]

9.1.3 Socio-Economic Dimensions of Vulnerability

Bangladesh is a low-income country with many development challenges. Although it has achieved an annual average growth rate of 6 % over the past decade, and made significant progress towards achievement of the Millennium Development Goals (MDGs), around one third of its population still lives below the poverty line and 17 % or some 27 million people still live in extreme poverty (Household Income Expenditure Survey 2010).

During 1980–2008, country was affected by 219 natural disasters or more than seven disasters per year causing over USD16 billion in damage and most of them climate induced water related. Naturally, one of the most pressing development challenges for Bangladesh is the protection of the population and resources from the disasters that regularly devastate the country and turn the clock back on development gains. According to a UNDP estimate, Bangladesh, situated on one of the globe's largest river delta, is the world's sixth most vulnerable country to flood. In a normal flood year, nearly 20 % of Bangladesh's land mass is covered by nutrient-rich, manageable floodwaters. Yet during a periodic or disastrous flood, such as that of 1998, up to 68 % of landmass can be covered causing tremendous damage.[3] Bangladesh's geographical position also puts it regularly in the path of tropical cyclones from the Bay of Bengal. For the numerous and densely populated communities who live along the coast line, these cyclones and the tidal surges they cause not only represent immediate danger but also means loss of livelihood through loss of cultivable land associated with increased water salinity and raise in water tide level over time. Arguably, the most

[2] Golam Rasul and A.K.M Jahir Uddin Chowdhury: Equity and Social Justice in Water Resource Management in Bangladesh, IIED, Gate Keeper Series, London, July 2010.

[3] Quoted from: Supporting Transformational Change: Case Study #6: Bangladesh: Disaster Risk Reduction as Development, UNDP, NY, 2012.

significant measure of this success in disaster and climate risk reduction interventions are contributing factors for the dramatic reduction in lives and livelihoods destroyed when natural disaster strike. Historically deaths from single events such as cyclones in Bangladesh have reached into the hundreds of thousands. However, progressively higher investment in disaster risk reduction mostly on embankment and cyclone shelters shows that the general trend has been steadily downwards.

The predicted effects of climate change will compound this already-complex disaster scenario which calls for huge adaptation investment in disaster and climate risk reduction initiatives. The UN Environment Programme identifies Bangladesh as the most vulnerable country in the world to rising sea levels, highlighting that a 1.5 m rise would submerge 16 % of the country and directly affect 17 million people. This is in addition to effects already being felt through the increased frequency and severity of sudden-onset disasters like floods or cyclones, or slow-burn threats like drought caused by heavy siltation and low dry-season water levels that decimate agricultural production (IPCC 2001).[4]

9.2 Adaptation Strategy and Equity and Justice Implications

This chapter is in favour of two approaches in adopting adaptation strategy in natural resource management particularly water resource management to follow the management principle of the common pool resources being the last resort to maintain minimum space for the environmental integrity as well as survival of the vast majority of rural resource poor people. Strategy is to create an enabling condition for the rural poor people organizing under the cooperatives to enable them accessing and management of common pool resources for their benefit and at the same time providing the environment services to the wider society.

Another principle is the emphasis on non-structural approach of adaptation strategy with due consideration of equity and justices could be drawn effectively based on assessment of vulnerability. Very often, vulnerability assessment of water resources incorporates only physical components consisting, for example, of water scarcity calculations using the water scarcity index which can be defined as the ratio of water demanded to the supplied volumes. Following this index, a number of studies have been carried out at the global scale (Vörösmarty et al. 2000). However, annual level assessment of water scarcity does not incorporate the fact of inter-annual seasonality as well as socio-economic implications. For example, large parts of monsoon Asia suffer from severe water scarcity in dry periods while the average annual resource availability appears to be plentiful. In addition to this, as stated above, the water scarcity calculation considers water only as a "physical resource", rather than as one component of a much broader and more complex water resource system.

[4] International Panel on Climate Change.

Researchers working with adaptation assume that climate changes are to some degree inevitable or it may be more efficient to rely on adaptation than mitigation. Adaptation refers to all those responses to climate change that may be used to reduce vulnerability or to actions designed to take advantage of new opportunities that may arise as a result of climate change (Burton et al. 1998). "Adaptation involves adjustments to enhance the viability of social and economic activities and to reduce their vulnerability to climate, including its current variability and extreme events as well as longer-term climate change" (Smit 1993, quoted in Smit et al. 2000).

Discussion of vulnerability and adaptation in developing country contexts often highlight the importance of poverty and inequality- or differential resource access (Adger and Kelly 1999). Kates (2000) argues that different groups and places within countries differ in their ability to adapt and that division between rich and poor translate into differentials in people's ability to adjust and in access to adjustments. This author argues for a focus on poor people, rather than a focus on poor countries, in efforts to facilitate adaptation among the global poor.

Environmental management and mismanagement are moving toward the centre of the adaptation debate. The "Summary for Policymakers" in IPCC (2001) states, "Policies that lessen pressures on resources, improve management of environmental risks, and increase the welfare of the poorest members of society can simultaneously advance sustainable development and equity, enhance adaptive capacity, and reduce vulnerability to climate and other stresses."

Given the socio-economic condition of Bangladesh, there are several strong reasons to adopt anticipatory rather than a reactive strategy (World Bank 2000). These include:

- Some impacts of climate change are gradual, long term and may be irreversible. Changes in long-term trends may lead to deaths, species extinction, or loss of valuable ecosystems, which cannot be reversed. Anticipatory measures strive to ease or change these trends.
- Some impacts of climate change increase the intensity of extreme events, such as cyclones and floods. While reactive measures are used to respond to the latest events, anticipatory measures mainly aim to increase the effectiveness and efficiency of such reactive measures.
- Long-term performance of some decisions and investments may be affected by the impacts of climate change. Major infrastructure works such as dams are designed to last several decades. If their design does not take climate change into consideration, their effectiveness in providing services might be under stress in the future.

The anticipatory adaptation measures in Bangladesh context should be aimed at taking measures to reduce vulnerability by (a) minimizing the negative impacts of climate change, or (b) enabling reactive adaptation to come about more efficiently. Reducing vulnerability should be directed towards making the system (both resource and users) functional under a wider range of conditions as well as a system which is flexible to respond to quick repair and adapts itself (World Bank, Report No 21104-BD, 2000). Particularly institutional arrangements demands for a new strategic reform intervention in order equip to address the complex issues of climate change impact through coordination, integrated planning, information management, research and international action (World Bank, op cit.).

While Bangladesh is already suffering from major extreme events, and is relatively well equipped in disaster response, the country lacks the capacity and mechanism to account for long-term changes. There remains a serious lack of real time data in monitoring and preparing for these events. Given the overriding importance of the coastal and water resources in the development of Bangladesh, such vulnerability remains a key threat to the country's potential for sustainable development.

9.3 Climate Impact on Water Sector and Likely Investment

Potential and existing impacts on life and livelihood due to climate variables and its variability needs to be addressed are mostly centred on water resource management. Bangladesh Climate Public Expenditure and Institutional Review Study[5] identified likely investment against climate impact variables and impacts by sectors as shown in Table 9.1.

Both Climate Trust Fund and Multi donor Climate Trust Fund known as Bangladesh Climate Resilience Fund gives emphasis on priority investment in Coastal Zone Management from the perspective of climate change adaptation. Changing hydro-meteorological dynamics in the face of emerging climate change scenario calls for water regime specific vulnerability analysis to design need responsive pro-poor appropriate techniques and technology in water resources management with blending of soft and hard technology ensuring eco-friendly solution with equity and justice consideration. In this context it is worthy to refer the fact that historically; much attention has given on engineering solution such as using hard structures including polders for protection of agricultural land from salty tidal wave and seawalls to protect coastlines susceptible to sea level rise. A number of feasible "soft" protection and adaptation options are also possible. However, integrated coastal zone management and ecosystem-based adaptation are proven frameworks that can facilitate the implementation of appropriate accommodation strategies. These strategies include measures such as coastal forest rehabilitation, beach dune restoration, and design structures that take the dynamic changes in the coastal zone into consideration. In many cases, these accommodation strategies—such as constructing homes on stilts rather than surrounding them with barriers—may provide a more cost-effective and resilient approach for adaptation. Where such measures are not possible, some communities may have to undertake a policy of retreat,

[5] Public Expenditure in Climate Change: Bangladesh Climate Public Expenditure and Institutional Review (CPEIR), GED, Planning Commission, Government of Bangladesh, supported by UNDP, Dhaka, May 2012.

Table 9.1 Climate variables, potential impacts and likely area of investments[a]

Climate variables	Potential impacts	Likely investment in water sector
Cyclones (increased frequency and severity)	Storm surges Wind speed	Early warning systems Cyclone shelters and raised land (*killas*) Dykes/embankment construction
Heavier, erratic rainfall in monsoon	Higher river flows Drainage congestion Flooding in rural/urban areas	Early warning systems Improved O&M of embankments Design upgradation of flood protection Irrigation/water supply projects Improved water management Homestead raising/raising roads/railway tracks Flood proofing improved/resistant crops, changes in cropping systems
Lower and more erratic rainfall in other seasons	Droughts and scarcity of drinking water	Improved irrigation and water management Provision of drinking water/improved/resistant crops, changes in cropping systems
Melting of Himalayan glaciers	Often higher river flows in short to medium term Often reduced flows and increased saline intrusion	Dykes/embankment construction Provision of clean water
Sea level rise	Coastal embankments overtopped Saline intrusions into surface water and groundwater Drainage congestion Migration and higher urbanization in main lands	Design upgradation of coastal protection Improved O&M Improved/resistant crops, changes in cropping systems/improved and redesigned drainage system Provision of portable water/human relocation Industrial relocation
Warmer and more humid weather	Increased prevalence of disease and disease vectors	Health education/awareness/knowledge development/immunization/other prevention programmes/provision of clean water Provision of sanitation

[a]*Source*: UNDP (2012), quoted in the CPEIR Report of GED, Planning Commission, GOB, Dhaka, May 2012

relocating away from vulnerable areas. Needless to say, this alternative has serious implications for land ownership and compensation (Michel and Pandya 2010).

9.3.1 Adaptation to Flooding in Bangladesh

Floods are already a major on-going concern of Bangladesh and this problem may be exacerbated by global climate change. Some climate model projections suggest that the greenhouse effect will enhance both ends of the hydrologic cycle, producing more instances of extreme rainfall as well as increased drought (Hansen et al. 1989;

Golitsyn 1989). Thus, floods may become an even greater threat as the world warms. In some instances, the expected rise of sea-levels may aggravate the vulnerability of coastal countries to floods. The floods of 1987 and 1988 proved very damaging to Bangladesh, forcing millions of people from their homes for long periods of time. The flood of 1998 is considered to be one of the most natural disasters by the country in the twentieth century as it continued for 65 days and affected about 68 % of the geographical area (Chowdhury 1998). Approximately 1.3 Mha of standing crops were fully or partially damaged. Total economic losses amounted to US$3.3 billion (8 % of GDP, 1998 value), according to a study by Chowdhury and Khouri (1999). It is fact that the people of Bangladesh showed a remarkable resiliency to the 1988 flood, which help facing flood of similar magnitude occurred in 1998, 2004 and 2007 and this ability to adapt will be increasingly important to coastal countries that will experience increased inundation even under a low climate change scenario.

Over 80 % of the population lives in rural areas, and over half still depends on agriculture for livelihood. Increasing population density and agriculture dependence compels people to inhabit flood-vulnerable areas, intensifying flood impacts and placing severe constraints on flood control options.

The response of the foods of 1988 has been a renewed emphasis on flood protection. A series of studies of “the Bangladesh flood problem” culminated in a Flood Action Plan-FAP (World Bank 1989) involving some 26 component studies covering a wide range of issues. As ISPAN (1992) explains, opinions can be distilled into two opposing approaches for dealing with abnormal flooding:

- Bangladesh cannot be left to suffer disastrous floods indefinitely. All major rivers need to be progressively contained, so as to reduce the risk of abnormal floods and thereby enhance economic activity.
- It is technically and economically infeasible to prevent abnormal flooding, and embankments would create as many problems as they solve. A better approach is to build on the ability of Bangladeshis to cope with, and recover from, flooding.

These proposed interventions ranging from an almost purely structural “once-for-all” massive engineering solution, to a mainly non-structural “living with the floods” approach. The debate was subsequently short-circuited by a set of 11 principles prepared to guide future studies; directives from senior levels of Government to proceed despite the unresolved issues; and also, in part, international commercial interests that favored structural interventions.

FAP was strongly opposed by local and international NGOs, organized around a coalition of environmental NGOs that initially raised awareness through public meetings outside Bangladesh. The opposition to FAP challenged a number of basic assumptions related to structural flood control, among these, that flood control was desirable; that the major rivers could be embanked sustainably despite large sediment loads and alluvial soils; that structural measures were affordable; and that planners could work in isolation from the people for whom the interventions were intended. The FAP process gradually produced a consensus on several issues, among them support for a softer “controlled flooding” concept in place of the more hard-edged idea of “flood control;” the need for greatly enhanced people's participation; and an emphasis on improving drainage through dredging planned at the river system level. In the end, the FAP did not recommend large-scale works; rather, it initiated guidelines on people's participation and environmental assessment which takes care of equity and justice issues as well.

9.3.2 Climate Change Adaptation and Environmental Impact of Flood Control Projects

A common strategy employed to reduce the flood and tidal surge threats is to construct embankments and coastal polders. The coastal polders consist of about 5,000 km embankment and about 2,500 water control structures. A total of 5,695 km of embankments, including 3,433 km in the coastal areas, 1,695 flood control/regulating structures, and 4,310 km drainage canals have been constructed by the Bangladesh Water Development Board during the last several decades. A controversy of the long-term effectiveness of embankments exists in Bangladesh where flood embankments have been the cornerstone flood control plans. Between the 1950s and 1980s there has been enormous government and donor expenditure on constructing embankments along the country's major and secondary rivers and coastal front, but the country remains exposed to devastating floods.

At present, existing polders, an early warning and evacuation system, and more than 2,400 emergency shelters to protect coastal inhabitants from tidal waves and storm surges. However, in a changing climate, it is estimated that 59 of the 123 polders would be overtopped during storm surges and another 5,500 cyclone shelters (each with the capacity of 1,600 people) to safeguard the population would be needed. Investments including strengthening polders, foreshore afforestation, additional multi-purpose cyclone shelters, cyclone-resistant private housing, and further strengthening of the early warning and evacuation system would cost more than $2.4 billion with an annual recurrent cost of more than $50 million. However, a conservative damage estimate suggests that the incremental cost of adapting to these climate change related risks by 2050 is small compared with the potential damage in the absence of adaptation measures.[6]

Embankments have been a central feature of water management for rivers in Bangladesh. For some rivers in Bangladesh, such as the Ganges and the Gumti, the social and environmental effects of embankments have been positive. For others, including a few rivers in the northwest and north central regions, embankments have caused significant technical, social, and environmental problems such as (a) lack of replacement land (b) lack of employment for the displaced, (c) opposition to placing the embankment at a safe distance from the river by people living outside the embankment, (d) embankment cutting by people on the river side who believe that

[6]Susmita Dasgupta et al. (2010) Vulnerability of Bangladesh to cyclones in changing climate: Potential Damage and Adaptation Cost, Policy Research Working Paper 5280, The World Bank. Web at http://econ.worldbank.org.

Table 9.2 Cost of adapting to tropical cyclones and storm surges by 2050 ($ million)

Adaptation option	Baseline scenario (existing risk) (1)		Baseline scenario (additional risk due to CC) (2)		CC scenario [total risk = (1) + (2)]	
	IC	AMC	IC	AMC	IC	AMC
Polders	2,462	49	893	18	3,355	67
Afforestation			75		75	
Cyclone shelter	628	13	1,219	24	1,847	37
Resistant housing			200		200	
Early warning system			39	8	39	8
Total	3,090	62	2,426	50	5,516	112

Source: World Bank (2010)

CC climate change, *IC* investment cost, *AMC* annual maintenance cost

cuts will abate a flood, and by people on the other side whenever there is drainage congestion (e) unstable river movement resulting in severe bank erosion, (f) obstructing the movement of fish to the floodplain inside the embankment, thereby reducing capture fisheries that sustain many of the poorest people (g) possible changes in aquatic ecosystems and water quality in some areas.

9.3.3 Adaptation Cost Issues in Water Sector[7]

The human cost of embankment construction varies greatly between countries, but globally it is insignificant. Locally it can be devastating. A disproportionate number are people from tribal or landless people. A total of USD 13.69 billion is estimated as incremental adaptation costing for major investment components in the water sector. Majority of the investment proportion is planned to be invested for the flood management (26 %) followed by protection of coastal zone (23 %), irrigation and drought management (22 %), water supply and sanitation (14 %), urban drainage (12 %) and erosion control and dredging (3 %). By 2050, total investments of $5,516 million and $112 million in annual recurrent costs will be needed to protect against storm surge risk, including that from climate change, of this, strengthening 43 polders against existing risks requires investments of $2,462 million and annual recurrent costs of $49 million. World Bank estimated (WB 2010) cost of adaptation for tropical cyclones; storm surges and inland flooding are shown in Tables 9.2 and 9.3. It is important to note that cost of lost livelihoods options and ecosystem based services as a special case under climate threat is missing in such exercise.

Tropical cyclone-induced storm surges. Since the 1960s, Bangladesh has made significant investments in embankments, cyclone shelters, and coastal afforestation and in disaster preparedness to address the risks from cyclones and storm surges.

[7]Bangladesh Water Sector Assessing the Investments & Financial Flows Required to Adapt to Climate Change.

Table 9.3 Total adaptation cost for inland flooding by 2050 ($ million)

Adaptation option	Investment cost	Annual recurrent cost
Transport—road height enhancement	2,122	42
Transport—road cross-drainage	5	–
Transport—railway height enhancement	27	1
Embankment—height enhancement	96	2
Coastal polders—cross drainage	421	8
Erosion control program		1
Total costs	2,671	54

Source: World Bank (2010)

However, these investments are not sufficient to address the existing risks and much less the future risk from climate change. Adaptation measures evaluated were (a) embankments, (b) afforestation, (c) cyclone shelters, and (d) early warning systems. Protecting Bangladesh against existing storm surge risks requires $3,090 million in initial investments and $62 million in annual maintenance costs. Addressing the additional risks due to climate change will require additional investments of $2,426 million and annual maintenance costs of $50 million by 2050 (Table 9.3). Despite differences in methodology, climate scenarios, economic assumptions, and scope of coverage, these costs are of the same order of magnitude as the adaptation costs estimated for Bangladesh from the global track of the study of around $13 billion over the 40-year period.

9.4 Types of Adaptation Measures in Water Sector and Equity and Justice Issues

Adaptation response to water crisis due to increase warming and scarcity of water source, construction of big irrigation canals establishes relatively large farmers' property rights over water. Small and marginal farmers, who use natural water bodies to irrigate their farms using traditional methods, consequently face difficulties that often affect their livelihoods with stress from climatic factors. Most of the flood control and water conservation projects benefit the richer sections of society by creating opportunities for culture fisheries or fish farming, but the poor do not have enough capital to invest in culture fisheries.

Proponents of embankments as one of the options for adaptation measures tend to hold the view that if all the social and economic implications of most projects are taken into consideration, with clear description of benefits that accrue to regions and nations as a whole, the advantages of these projects outweigh their disadvantages. For opponents of large dams and embankments, if all the social and environmental costs of large dams and embankments are taken into account, particularly how land and livelihoods have been affected, the magnitude of the disadvantages of such projects would appear clearly and would call such interventions into question. This part is discussing the issues on embankment as one of the options for adaptation to climate change measures as on-going initiatives with Climate Resilient Fund (Multi-donors climate trust Fund) and Climate Trust Fund of the government's own resource as well as Priority Pilot Resilience Projects (PPRC) has a common consideration on strengthening of coastal embankments as a means for adaptation to climate change. This chapter emphasizes the adoption of past learning to avoid the hidden risks and long term hydro-ecological disasters.

Thompson and Penning-Rowsell (1994) examined the impact of a major flood control, drainage and irrigation (FCDI) project on households and compared with conditions in a flood prone area. They assumed that in flood prone areas unusual floods would cause loss of agricultural production and other damages, thus reducing incomes, and that poor households would be more vulnerable to this becoming a disaster, resulting for example in sales of assets including land.

In their study, they also found that if embankments breach then agricultural losses are likely to be greater than they might have been without a project. Subsequently in that project there has been a dramatic increase in agricultural production, but it remains to be seen whether expected agricultural returns will be greater with projects (but they would now appear to be higher). However, household vulnerability has not clearly been reduced by flood protection given the uneven distribution of benefits, the continued variation in agricultural performance, and the increased losses when projects fail. Loss of land to the embankment and other projects, often with inadequate compensation, has also added to the disproportionate distribution of benefits causing strains on social integration.

It is evident from Bangladesh experience that the material damage is comparatively worse inside the embankment than in areas outside subject to either breaching or drainage system failure leading to waterlog situation. Embankments impede the movement of freshwater fish and cut off their spawning areas, threatening the occupation of more than a million fishermen and jeopardizing the already marginal supply of animal protein in the diet of the majority of the population. Fisheries supply over 70 % of animal protein in a typical diet in rural Bangladesh. Last but not least, embankments deprive the farmers from the beneficial effects of "normal" seasonal floods. Normal annual flooding in Bangladesh, known as *borsha*, is a part of peasant life and is viewed as a beneficial phenomenon (Paul 1984). It produces leaching and eluviations processes which have rejuvenated the soil water properties and fertility of soils in the region for centuries.

Current coastal embankments in Bangladesh are not designed to deal with 50- and 100-year storms. Embankment failure is therefore a serious possibility which is proven during the super cyclone Sidr in 2007 and Cyclone Aila in 2009. Due to breaching in embankments and submergence of the protected areas for a longer period forced migration of the inhabitants. Increased salinity has also converted agricultural land not cultivable for a near future pushes people migration into cities from rural areas. This is another emerging problem of population displacement, migration and overcrowding cities making the management of employment and services for large numbers of migrants. The latter problem may be compounded in coastal cities, where ground water is likely to become more saline.

Table 9.4 Estimated figure of embankment construction over years and percentage damage saved

Year	Embankment (km)	Benefited area (km^2)	Storm surge height (m)	Potential damage saved area (km^2)
1985	3,661.33	7,569.82	4.6	1,062
1991	3,661.679	9,216.536	6.7	0
1997	4,252.411	10,395.752	4.6	1,233
2007	4,588.835	10,985.36	4.6	1,331

Source: UNDP commissioned study to CEGIS on Disaster Risk Reduction Investment Reduces Costs of Response: A case study on Cyclone, prepared based on BWDB data, 2009

Even if the proposed embankment succeeds in achieving its flood control aims, it is likely that the accelerated bank erosion of these braided rivers might outweigh the benefits in this land scarce country (Table 9.4). This is because riverbank erosion hazards can lead to the displacement of hundreds of people, and this effect becomes a permanent feature, whereas the effects of seasonal flooding are temporary (Haque 1988).

Water logging created by embankments has long-term impacts on the local environment, society and economy. It has particularly affected the agrarian community, landless and marginal people. Farmers and landless people engaged in farming activities are now compelled to change their occupational status due to water logging (Haque and Zaman 1994). People living in the area are facing serious energy crisis due to loss of trees, plants and crop residues. The ecology and environment as well as biodiversity have radically been changed due to water logging. Even the availability of livestock and poultry has declined due to the situation. As a consequence, consumption of animal products has decreased. The female members of the households especially the poor, destitute and vulnerable women face hard times who are primarily responsible for procuring drinking water and cooking fuel from locality. They have to travel longer distances to collect drinking water and fuel. Many of the children have stopped going to schools due to breakdown of communication resulting in the lower literacy rate.

The above discussions reveal the fact that some groups of people tend to be net losers from embankment projects, as they are disproportionately affected by negative effects of embankments while almost excluded from access to benefits generated. The paper makes the point equity is more concerned about protecting the poor, the vulnerable.

Equity directs attention to those who are more at risk—the people whose interest are less likely to be acknowledged and protected. Thus equity points to the vulnerabilities of isolated, less powerful populations, indigenous cultures, women and all for whom development can all too easily mean loss. Similarly, the issue of distribution arises in relation to those who will not benefit from a project, and is concerned to identify where the distribution of benefits has the potential to be unfair. This focuses more on those at risk of being net losers and is less concerned about the overall or macroeconomic nature of distribution.

There are streams of benefits and costs at the various stages of embankment projects. Some of these impacts are tangible others are not; some are directly attributable to the embankments while others are indirect effects. Some of the impacts might manifest themselves at early stages, others take several decades before being noticed. Some of the impacted groups live in the vicinity of river/coastal embankment, while others live in remote areas and even distant countries.

9.5 Adaptation with Equity and Justice: Lessons from the Coastal Flood Management

Flooding is a natural phenomenon, which cannot be prevented. Complete flood control is not in the interest of most Bangladeshi farmers. The flood control measures and policies should be directed to mitigation of flood damage, rather than flood prevention. Resources should be allocated to help people to adopt a life style that is conformable to their natural environment such as in coastal area tidal river management. Adaptation strategies such as changing the settlement pattern prefer for disaster resilient cluster village, cyclone resilient housing structures and climate resilient crop patterns can help reduce flood or drought damage. Moreover, good governance, appropriate environmental laws, acts and ordinances will be necessary to achieve sustainable economic development and to reduce any environmental degradation. In addition, implementation of an improved real-time flood and drought control warning system can reduce damage caused by disasters. Therefore, structural solutions, such as the building of embankments along the rivers and polders in the coastal regions in Bangladesh, will not solve the flooding problems, but will result in many adverse environmental, hydrologic, economic, social, ecological, and geologic consequences. Solutions to flooding problems can be achieved by adopting and exercising ecosystem based adaptive natural resource management practices including agriculture, fisheries, horticulture, forestry, sustainable land use planning, rain water harvesting, renewable energy promotion, good governance, river and water resources management, urbanization, flood forecasting, and regional cooperation.

Despite all these steps that have been taken, there are still numerous things that need to be further addressed to achieve equity and social justice in water sharing and allocation of water resource management. In order to make the most equitable decision, one has to consider and evaluate the interventions on the basis of their hydraulic, environmental, ecological and socio-economic consequences. Hence for water management to be equitable, planning needs to encompass the following:

- Ensure pro-poor multi-stakeholder based objective planning;
- Form water and ecosystem-based local management zones through a participatory approach;
- Ensure informed decision making with detailed information based facts and figures public participation.

Complete flood control is neither feasible nor desirable. Lessons from other countries suggest that a combination of measures is the most useful approach: flood control structures, flood proofing, and managed diversion of floodwater that does not threaten the ecological balance.

Valuable lessons for managing floods and water resources in Bangladesh are the need to:

- Include the ultimate beneficiaries in all stages of project development.
- Integrate structural and non-structural measures for both flood mitigation and water management, covering protected and unprotected areas alike.
- Upgrade methods of flood forecasting and warning, flood proofing and disaster management, and floodplain zoning.
- Provide sound embankments to protect urban areas from flooding.
- Introduce controlled flooding to rural areas, and compartmentalize water management.
- Stress bank protection and river-training works, not just for social and economic reasons but also to safeguard the water management infrastructure.
- Ensure that all users receive their fair share of water as availability declines in the dry season.
- Improve flood flow conveyance and land reclamation in both coastal and riverine areas and introduce active floodplain management.
- Adhere to guidelines for project planning and implementation, including those for project assessment, environmental impact assessment, and public participation.

Climate change adaptation should be part of community-based development, and should focus on strengthening institutions and economic resources, as well as making information, skills training, and technology readily available. Adaptation requires two approaches: systems-based risk management (using the principles of disaster risk reduction in the Hyogo Protocol) to protect the assets communities currently have, and the development of more diverse, less climate sensitive, sustainable livelihoods. The main role of governments and international institutions is to support local adaptation initiatives with appropriate policy frameworks. Communities should have the power to shape adaptation policies using their own priorities, experiences, and traditional knowledge, and communities and practitioners should share lessons from successful adaptation projects.

9.6 Bangladesh Delta Plan (BDP): A New Climate Adaptive Strategic Water Resource Plan

Bangladesh Delta Plan is under process for a strategic long term plan for climate adaptive water resource management with target for 100 years. It will draw experiences and knowledge from all the existing studies and sectoral plans (Perspective Plan 2010–2021, SFYP 2011–2015, National Water Management Plan (NWMP), Hoar Development Master Plan, Southern Agricultural Master Plan, CIP, ICZMP). The BDP will be an indicative plan. The Perspective Plan 2010–2021 was used for preparing the Sixth Five Year Plan having elaborated and giving more details. Broad stakeholder views will be incorporated into the BDP. It will allow to start preparing 7th Five Year Plan (FYP) expected to start mid 2013. All the previous plans are the building blocks for the Bangladesh Delta Plan.

It was noted that the National Water Plan, approved by National Water Council, has a 25 years' time frame. The difference that can be seen is that NWP was housed in WARPO, and reporting to the MoWR. Whereas, BDP looks similar but is hinged to Planning Commission, which is a central ministry. In addition to the Planning Commission the Bangla-Dutch Delta Committee will assist the BDP. In addition to NWMP all the sectors have some plan with different time frame and their coordination under the umbrella of BDP is the main challenge. The Planning Commission will coordinate all these ministries and can give a shape of an integrated plan. For Bangladesh this is new to have such longer term planning. In the recently formulated Southern Master Plan agricultural development, initiated by the Minister of Agriculture, it is tried to plan for high cropping intensity for the 14 districts in the south, having integrated with fisheries and livestock sectors. However, it is well understood that nothing could happen if water infrastructures are not right, and local government and environmental issues are not involved. Under the Agri-Master plan so far 22 priority intervention areas have been identified, resources requirement are determined and investment priorities recommended. It is expected that the Planning Commission will assist in finding the means how to fund it. The Ministry of Agriculture has reviewed the plan through its Inter-ministerial Steering Committee, and already indicated that the Delta Plan will be taken as a benchmark/guidance.

It was discussed why the Delta Plan is needed: Bangladesh has polders and embankments which were established starting about 50 years ago. These have not been maintained all in the same way and some are damaged. Water logging inside the polders is a major problem, where three crops used to grow, now one crop only. The farmers are to pump the water out for planting boro rice. The vision for the structure was not for long term. We need to look into the long term issues. Recently a team from the Ministry of Agriculture has visited the Mekong Delta. The Vietnamese have wonderful plans, many canals, everywhere gravity irrigation, no water logging. Good crops. Under this plan, Bangladesh will take lesson from their experiences and knowledge for their implementation in Bangladesh. Ownership of the document is important. It was indicated that a website will be made available (note: action has been taken—on www.bangladeshdeltaplan.org the report of the preparatory team and a brochure summarizing the report, including a summary in Bangla, can be found).

9.7 Concluding Remarks

Policy and strategies for adaptation to climate change in water resource sector being a cross-cutting issue needs deeper understanding on hydro-metrological dynamics as it relates to broad based ecosystem and its socio-economic interactions as it has critical implications in equity and justice dimensions in decision making process. In this context, key objective of this chapter is to highlight policy advocacy for (a) participatory ecosystem based decision making process, (b) multi-stakeholder need responsive investment plan; (c) cross-sectoral pro-poor programme design with common pool resource options and (d) knowledge based decision guided by vulnerability assessment including social, economic and environmental impact analysis and (e) careful analysis of cost–benefit with clear understanding who gets what in short term and long term basis. This will provide existing resources use more efficiently from the sustainable development perspective with equity and justice dimension. In order to make the most equitable decision, one has to consider and evaluate the interventions on the basis of their hydraulic, environmental, ecological and socio-economic consequences. Moreover, good governance, appropriate environmental laws, acts and ordinances will be necessary to protect and guide assurance role towards achieving sustainable economic development and to reduce any environmental degradation and climate risks. From climate change perspective, the rationale for a synergistic pro-poor adaptation policy is based on the premise that increased adaptive capacity is a first and most logical response to the complex threat of climate change.

The focus of water resource development in Bangladesh is still very much biased towards coastal embankment, flood control, drainage and irrigation in order to support the sole agricultural sector with limited inputs from local people and often ignores the other uses of water, particularly those on which the subsistence of poor people are based. This ignorance by the policy and planners on the single sector focus with a tunnel vision without considering geomorphologic, hydrometrological, ecosystem based adaptation as well as socio-economic stakeholders view create the option for slow-onset another hydro-ecological disaster for future and contributing to the persistent in-equality in socio-economic context as a part of vicious circle of poverty.

For Bangladesh, the policy makers and donors should invest more intelligently in risk areas to get greater benefits of response at much lower costs with assurance of enhance resilient with benefits shared on equity basis. Bridging the scientific climate scenario with the community at risk and hydro as well as agricultural scientists and their extension link with the community is a critical need as a part of meeting risk reduction challenge. Facilitate peoples social capital and enhance their resilience is important to add value to this endeavor with local level water risk management contingency plan development and management preparation with skill and resource in place. In conclusion, equity and justice issues in water sector management plan from the perspective of disaster risk reduction and climate change adaptation should follow the principles of right based approach with wise use of natural resources so that socio-economic inequality and ecosystem values are not ignored at policy, programming, budgeting and planning of the project design cycle.

References

Adger WN, Kelly PM (1999) Social vulnerability to climate change and the architecture of entitlements. Mitig Adapt Strat Glob Chang 4:253–266

Ahmad QK (2003) Towards poverty alleviation: the water sector perspectives. Water Resour Dev 19(2):263–277

BBS (2010) Household Income & Expenditure Survey -2010. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning

Burton I, Smith JB, Lenhart S (1998) Adaptation to climate change: theory and assessment. In: Handbook on methods for climate change impact assessment and adaptation strategies [Feenstra JF, Burton I, Smith JB, Tol SJ (eds)]. United Nations Environment Programme and Institute for Environmental Studies, Free University of Amsterdam, Amsterdam, pp 5.1–5.20

Chowdhury AM (1998) Flood '98; oceanic perspectives. Paper presented to the National Seminar on Flood 98 and Management of Floods in Future, organized by Jatio Tran Committee, Dhaka University and others, 8 December 1998

Chowdhury S, Khouri N (1999) Mitigating arsenic in Bangladesh's groundwater: early policy lessons from a development project. In: Groundwater: legal and policy perspectives: Proceedings of a workshop. World Bank Technical Paper no. 456

Divan S, Rosencranz A (2005) Environmental law and policy in India, 2nd edn. Oxford University Press, New Delhi

Golitsyn GS (1989) Climate changes and related issues, Presentation 24 August 1989 at Sundance, Utah Symposium on Global Climate Change

Hansen J, Rind D, Del Genio A, Lacis A, Lebedeff S, Prather, M, Ruedy R, Karl T (1989) Regional greenhouse climate effects. In: Coping with climatic change: proceedings of the second north american conference on preparing for climate change. Topping JC Jr. (ed). The Climate Institute. Washington, DC

Haque CE (1988). Perspectives on the integration of physical and human geography: an approach to natural hazards. In: Paul AH, Widdis RW (eds) The Moose Mountain papers. Regina Geographical Studies, No. 5. Department of Geography, University of Regina, Regina, pp 124–137

Haque CE, Zaman MQ (1994) Human responses to riverine hazards in Bangladesh: a proposal for sustainable floodplain development. World Dev 21:93–107

Intergovernmental Panel on Climate change (IPCC) (2001a) Climate change 2001: impacts, adaptation vulnerability. Contribution of Working Group II to the third Assessment report of the Intergovernmental Panel on Climate Change. UNEP/WMO, Geneva

Intergovernmental Panel on Climate Change (IPCC) (2001b) Annex B: glossary of terms. In: McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS (eds) Climate change 2001: impacts, adaptation and vulnerability. Cambridge University Press, Cambridge

ISPAN (1992) Impacts of flood control and drainage on vector-borne disease incidence in Bangladesh. FAP 16 Environmental Study, Special Studies Program, Irrigation Support Project for Asia and the Near East, Dhaka

Karim Z, Ibrahim AM, Iqbal A, Ahmed M (1990) Drought in Bangladesh agriculture and irrigation schedules for major crops, Bangladesh Agricultural Research Council (BARC), Soils Public. No. 34, p. 11

Kates R (2000) Cautionary tales: adaptation and the global poor. Climate Change 45:5–17

Michel D, Pandya A (2010) Coastal zones and climate change. The Stimson Institute, Washington, DC

Ministry of Water Resources (1999) Government of the People's Republic of Bangladesh

Paul BK (1984) Perception of and adjustment to floods in jamuna floodplain, Bangladesh. Human Ecology 12:3–19

Phansalkar SJ (2007) Water, equity and development. Int J Rural Manag 3(1):1–25

Saleth R, Dinar A (2004) Institutional economics of water: a cross country analysis of institutions and governance. Edward Elgar, Cheltenham

Smit B, Burton I, Klein RJT, Wandel J (2000) An anatomy of adaptation to climate change and variability. Climate Change 45:223–251

Syme GJ, Nancarrow BE, McCreddin JA (1999) Defining the components of fairness in the allocation of water to environmental and human uses. J Environ Manage 57:51–71

Thompson P, Penning-Rowsell E (1994) Socio-economic impacts of floods and flood protection: a Bangladesh case study. In: Varley A (ed) Disasters development and environment. Wiley, Chichester, pp 81–97

Tisdell JG (2003) Equity and social justice in water doctrines. Soc Just Res 16(4):401–416

UNDP (2012) Bangladesh Climate Public Expenditure and Institutional Review, General Economics Division, Planning Commission, published by Asia Pacific Regional Centre, United Nations Development Programme, Bangkok

Vörösmarty CJ, Green P, Salisbury J, Lammers RB (2000) Global water resources: vulnerability from climate change and population growth. Science 289:284–288

World Bank (1989) Bangladesh: Action Plan for Flood Control, Asia Region Country Department 1, Washington.

World Bank (2000) Bangladesh, climate change and sustainable development. Report No 21104-BD. World Bank, Rural Development Unit, South Asia Region

World Bank (2010) Bangladesh: economics of adaptation to climate change. World Bank, Washington, DC

Chapter 10
Gender and Climate Change: Impacts and Coping Mechanisms of Women and Special Vulnerable Groups

Md. Anwarul Abedin, Umma Habiba, and Rajib Shaw

Abstract Climate change poses challenges on a new scale for humanity, particularly for the populations of lower income countries like Bangladesh. There has been relatively limited in-depth analysis of the gender dimensions of climate change to date, partly because of the uncertainties of climate change science and the lack of downscaled data. Therefore, it is hard to predict how social changes are varied according to climate change. However, the literature indicates that women are disproportionately vulnerable to climate change, because they are more likely to be found in the poorest sections of society, have fewer resources to cope, and are more reliant on climate-sensitive resources because of the gender division of labor. Furthermore, climate change is now recognized as serious with long-term negative effects on human community and social vulnerability and is not gender-neutral. Women are often vulnerable to climate change impacts where their endowments, agency and opportunities are not equal to those of men. They are also more dependent for their livelihood on natural resources that are threatened by climate change. In the context of climate change, a "gender analysis" promotes an understanding of the ways that men and women are differently impacted by climate-related hazards and by adopting adaptation and mitigation strategies. This chapter highlights the baseline relation between gender and climate change, position of women and impacts of climate change on women vulnerability and special vulnerable groups and currently existing copping mechanism that practices by women and special vulnerable groups too.

Keywords Bangladesh • Climate change • Gender • Impacts and copping mechanism • Women vulnerability

Md.A. Abedin (✉) • U. Habiba • R. Shaw
Graduate School of Global Environmental Studies, Kyoto University, Kyoto, Japan
e-mail: masumagriculture@yahoo.com

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*,
Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_10, © Springer Japan 2013

10.1 Introduction

As predicted by the Intergovernmental Panel on Climate Change (IPCC) in 2001, "climate change impacts will be differently distributed among different regions, generations, age classes, income groups, occupations and genders". The IPCC also notes that the impacts of climate change will fall disproportionately upon developing countries and the poor within all countries, and thereby exacerbate inequities in health status and access to adequate food, clean water, and other resources. As, women represent about 70 % of the poor throughout the world, therefore, women are poised to bear the brunt the effects of climate change. Generally, in many developing countries women often live in conditions of social exclusion such as cultural limitations to mobilize outside their immediate environment; have less access to information to early warning systems in times of disasters, and to forecasts of climate variability; and have difficulties in participating in training processes (UNDP 2009). However, the effects of climate change are differentially experienced by men and women. Because women use and manage natural resources differently than men, and the degradation of natural resources affects them differently, women's disadvantages may increase with the change in or loss of natural resources associated with climate change. For example, rural women in developing countries are the principal producers of basic foods, and the agricultural sector is highly susceptible to risks of drought and uncertain precipitation; this means that climate change endangers food security as well as families' well-being and capacity to survive.

Natural disasters like floods or droughts, hurricanes or heavy rains, are already impacting livelihoods in many regions of the world. There are clear gender differences in the prevention of disasters (e.g. early warning systems don't get through to women), in emergency response (e.g. different risk reduction strategies and different needs), and in the reconstruction phase (e.g. gender differences in migration). It is often reported that when disaster occurs, more women die than men, which reflected women's social exclusion. For example, during the 1991 cyclone disasters in Bangladesh, 90 % of the 14,000 fatalities were women (Ikeda 1995). The reason lies behind that warning information was transmitted to men by men in public spaces, but rarely communicated to the rest of the family. As many women are not allowed to leave the house without a male relative they perished while waiting for their relatives to return home and take them to a safe place (Aguilar 2004). Peterson (2007) further mentioned that women, boys and girls are more than 14 times more likely than men to die during disaster. Aftermath of disasters, it causes women to work harder to secure (natural) resources and livelihood. Poor girls regularly drop out of school to help their mothers to gather wood and water in the changed harsher climatic condition (Baten and Khan 2010).

Across the world, Bangladesh is known as one of the most vulnerable countries under climate change. Most of the adverse effects of climate change will be in the form of extreme weather events, while water-related hazards such as flood, drought, salinity ingress, bank erosion, and tidal bore are likely to exacerbate, leading to large scale damages to crop, employment, livelihoods, and national economy. Vulnerability and adaptation to the adverse impacts of climate change are the most crucial concerns for Bangladesh. It is generally recognized that vulnerability to climate-related hazards and climate variability is contextual, where poverty as well as gender discrimination and prevailing inequity are major determinants which add complexity to perceived vulnerabilities to climate events. It is well understood that the women and disadvantaged people of Bangladesh will experience the worst adversities due to climate change. However, little information exists that could help identify vulnerable groups, particularly women and people with disability and special needs.

Gender, or the distinct social roles assigned to men and women, is a critical part of all development initiatives. A gender analysis is not a special focus on women, but rather, an understanding on how discrimination against women and gender roles interact to shape men and women's enjoyment of human dignity, rights, as well as quality of living. In the context of climate change, a "gender analysis" promotes an understanding of the ways that men and women are differently impacted by climate-related hazards and by adopting adaptation and mitigation strategies.

The overall goal of this chapter is to develop an information source on specific aspects of vulnerability of women and special vulnerable groups to climate change and their impacts and to analyze how these specific vulnerability contexts can be addressed by the women and special vulnerable groups with their indigenous knowledge and planned adaptation measures, given the sustainable development framework of the country. The study also covered, though to a much lesser extent, various other disadvantaged groups such as ethnic minority groups, physically and/or mentally challenged groups, etc. Finally, this chapter includes conclusion and few recommendation regarding women, special vulnerable groups and climate change.

10.2 Position of Women and Their Vulnerabilities

In the nineteenth and twentieth centuries, women achieved significant progress in the economically progressive areas dominated by Western culture, including North America, Europe, and Australia. In developing areas dominated by non-Western culture, however, women remain more or less subjugated, and in some countries they are stripped of any human rights (Cohen 2006). In Senegal, significant advances have been made on gender issues despite constraints related to women's rights, social, and economic empowerment. According to the report by Irene et al. (2008); Senegal has signed a number of international conventions and passed some laws. They are reinforced by the new Constitution of 2001 that reaffirms the principle of equity and gender equality and prohibits all forms of discrimination based on gender. The similar observation also found in case of Ghana where women and men occupy distinct positions in the economy largely as a result of a gender division of labor within households and the society at large. Again, South Asia is the continent where world's poorest population is habituating. Specific social features in South Asia include seclusion and limited mobility of women, and the exclusive nurturing role assigned to them in the gender division of labor. Cultural values, religious norms, and social structures force women and children to be dependent on men.

Most of the value systems in almost all South Asian societies believe in the need for protection of a male for women to carry on their life.

According to the socio-economic indicators, the illiteracy of the overall population is considerably high and the gender disaggregated data points out that female illiteracy is always higher than male (World Bank 1999). The ownership of assets shows a similar pattern where women own less assets, since most societies follow a patriarchal system of ownership of property. Some of the key factors contributing to women's "double edged" vulnerability owing to poverty and other social disadvantages in the South Asian context can be stated as follows:

- Very high illiteracy levels
- Low ownership of assets such as land, and other property (often inheritance laws are male oriented)
- Minimum work opportunities outside home
- Limited mobility out of home and out of their own locality
- Low social status
- Socially constructed dependency on male relatives

All these factors, the dynamics between men and women, and the processes arising from the inter-relationships between them has resulted in women becoming an extremely vulnerable group in South Asia.

In Bangladesh case, it has been seen that half of the population is made up of women (48.9 % in 2004, according to the World Bank gender profile), 80 % of whom live in rural areas (BBS 2001). Women bear multiple responsibilities at home, including food preparation, provision of cooking fuel, health care, and caring for children and their education. Likewise, women play an important role in a wide range of income-generating activities, but their contribution to the national economy is largely unaccounted for. Women in low-income households are heavily involved in economic activities, mostly around homestead-based production, which contributes up to 16 % of the household income in Bangladesh (CPD 2004). Independent livelihoods managed by women-headed households are also an important aspect of the rural economy of South Asia and contribute to 15 % of the rural households in Bangladesh (CPD 2001). Neither of these percentages are accounted for in the GDP.

Furthermore, women's contributions to rural production activities include raising seedlings, gathering seeds, post-harvesting, cow fattening and milking, goat farming, backyard poultry rearing, pisciculture, agriculture, horticulture, food processing, cane and bamboo works, silk reeling, handloom weaving, garment making, fishnet making, coir production and handicrafts. A significant number of rural women, particularly from extremely poor landless households, also engage in paid labor in construction and earthwork and field-based agricultural work, activities that traditionally have fallen within the male domain.

With the passing of time, a gradual change in social attitudes has allowed many women to take advantage of new economic and social opportunities, adding significantly to improvements in key development indicators. Participation of women in the wage labor force has increased, particularly in the ready-made garment (RMG) sector, where women make up over 90 % of the 1.5 million workers that currently contribute approximately 70 % of the country's foreign currency earnings; these earnings also enhance the incomes of many families (CPD cited in ADB 2004). Women migrants, mostly from female-headed households (FHHs), now contribute a major share of the informal urban labor market. Increased access to microfinance also has helped transform women's household labor into cash contributions to household income.

Due to increased access to services and cash, more women are able to use health services. As a result, female life expectancy has increased from 58.1 years in 1997 to 60.9 years in 2001, while that of men has increased from 58.2 % in 1997 to 60.1 in 2001 (ADB 2004). Female adult literacy rates have also increased from 27.4 % in 1997 to 30.8 % in 2001, while that of men has remained steady at 49.9 %. Increased literacy directly relates to increased employment opportunities for women. The rate of enrollment of girls in primary school is similar to the rate of enrollment of boys which reflects a change in the family and community attitudes towards the value of girls and their rights.

Although, women play a key role in household and community disaster recovery, but, discussions on the impact of disasters and recovery support favor livelihoods dominated by men. The policy assumption remains that women benefit once men's livelihoods are secured. This assumption is not well verified because of limited research on how women's own lives and livelihoods are affected by climate change and disasters.

10.3 Impacts of Women and Special Vulnerable Groups

This section will describe the actual and potential impacts of climate change on women's and special vulnerable groups lives and livelihoods.

Climate change is often perceived as a multi-dimensional environmental problem with a strong political and development component. The impacts of global climate change are not only physical and economic (for instance, in the form of natural disasters), but also social and cultural, threatening to jeopardize environmentally based livelihoods in many areas of the world.

The contexts of vulnerability to climate change are somewhat different for women, since they have lesser financial means and decision-making power than their male counterparts to respond to climate-driven stresses. Moreover, as being the household manager women have to bear the burden of meeting the needs of the family, even when fighting against adversities. Most climate change issues, policies and programs are not gender neutral. In light of this, several areas deserve attention, specifically: gender specific resource-use patterns; gender-specific effects of climate change; gender related patterns of vulnerability; women's capacity to cope with climate change; gender and decision-making on climate change; and gender aspects of mitigation and adaptation. Hence, impact of climate change on women and special vulnerable groups are illustrates in the following sub-heading.

Fig. 10.1 Life in disaster period

10.3.1 Impacts on Women to Climate Change

In view point of women's context of vulnerability with reference of physical and social setting; gender-poverty links show that 70 % of the poor in the world are women and their vulnerability is accentuated by race, ethnicity, and age (Enarson and Hearn Morrow 1998). When natural disasters and environmental change occur, women and men are affected differently because of traditional, socially-based roles and responsibilities (GTZ 2005). The impacts on women to climate change is briefly elaborates considering the following aspects.

10.3.1.1 Impact on the Lives and Health of Women

While there has been a significant decrease in disaster-related deaths in Bangladesh, data is gender-neutral, limiting the ability to determine how men and women are affected. But a few studies following the cyclone and flood disasters of 1991 revealed that, among women aged 20–44, the death rate was 71 per 1,000, compared to 15 per 1,000 for men (UNEP 2005). Again, following the cyclone and flood of 1991 in Bangladesh the death rate was almost five times as high for women as for men. Warning information was transmitted by men to men in public spaces, but rarely communicated to the rest of the family and as many women were not allowed to leave the house without a male relative; they therefore were perished waiting for their relatives to return home and take them to a safe place. Figure 10.1 illustrates how women survive in their own house in post disaster time.

Deaths, diseases and injuries occur from waterborne diseases, snake bites, drowning, slipping, large trees and structures falling on women, lack of medical facilities, malnutrition, lack of uncontaminated drinking water and lack of proper sanitation facilities. Women and adolescent girls suffer as sanitation systems are destroyed: many women reported that they refrain from using the toilet during the day and consequently suffer from urinary tract infections. Pregnant women, lactating mothers and differently disabled women suffered the most, as they found it difficult to move before and after the cyclone hit.

With increasing climate variability, salinization of drinking water sources is becoming a major problem for the people of southwest Bangladesh. During the dry season, when lack of potable water becomes an acute crisis for households, it becomes the responsibility of women, irrespective of their physical condition, to provide drinking water for their families. Since water sources in the neighborhood are all affected by high salinity, women need to travel long distances, sometimes up to 10 km on foot every day over rough terrain, in search of water. This consumes an enormous amount of their time.

10.3.1.2 Impact on Women's Physical Security and Dignity

Women in Bangladesh still experience various types of violence, and physical, sexual and emotional violence increases during and after a disaster (UNDP 2002).

(a) Domestic violence
As psychological stress increases during disasters, and more men are left without employment, male relatives of many women have been reported to vent this increasing frustration via abusive language or exertion of physical force. Reasons given for this abuse range from women not being able to manage resources properly, to not serving food on time, to not being able to procure relief materials.

(b) Harassment and loss of privacy in flood and cyclone shelters
Many women refrain from going to shelters during a disaster or when a warning signal is issued in fear that they would have to share a room with strange men. Pregnant women and nursing mothers tend to be reluctant to share space with or nurse in front of strangers. Some women with disabilities also mention facing some form of violence in shelters, including mental abuse and physical torture.

(c) Harassment in relief queues
Women often face additional physical insecurity and loss of dignity while collecting relief during or after a disaster. In many cases, they have to walk long distances through water, their wet clothes clinging to their bodies, to collect relief. During collection they have to stand in long queues with male strangers. Sexual harassment is often reported.

10.3.1.3 Impact on Women's Economic Livelihoods

Natural disasters viz. floods, cyclones and droughts damage livestock (i.e. cows, goats, buffaloes), poultry (i.e. chickens, ducks), fisheries, trees, crops (i.e. rice, wheat, nuts, chilies, lentils), seeds and animal fodder. Productive tools such as ploughs and nets are also washed or blown away. Increased salinity after a cyclone and the difficulty in plowing wet soil after flooding decreases soil productivity.

Sand deposition as a result of flood and river erosion affects production of crops such as nuts. During and after weather disasters, the lack of fodder for livestock and poultry results in reduced milk and meat production. The impacts on the livelihoods of women specifically include:

(a) Housing and homestead
The destruction of houses by floods and cyclones is a common impact in disaster prone areas. During and post disaster period of time, women and special vulnerable groups face tremendous difficulty for finding safer place to stay or living. They also fight for taking care of their house and homestead for their survival.

(b) Crop production loss
Climate change, which reduces crop yield and food production particularly in developing countries, affects women's livelihood strategies and food security, and therefore, their right to food. Bangladeshi women, who control homestead-based livelihoods, lose income when crops are blown or washed away.

(c) Livestock death
Cows and goats are the most valuable assets of poor people in flood and drought-prone areas. During flooding and drought period, collection of fodder for livestock is a significant challenge, particularly for goats who need green grass (which often becomes flooded). It also becomes difficult for veterinarians to visit the villages or for villagers to travel to buy medicine.

(d) Loss in productivity
With changes in climate, traditional food sources become more unpredictable and scarce due to loss in productivity. Floodwater and sand deposition decreases soil productivity which enhances loss of crop productivity in that particular crop field. Sand deposition also creates long-term problem of paddy crop field for better crop production.

(e) Supply shortage and price of inputs
Shortages during flooding leads to increased prices for inputs such as seeds, fertilizers, oil for running irrigation pumps, fodder for animals, transport costs and veterinary fees.

(f) Limited access to market
With damages to infrastructure and communications systems, women cannot access the market to buy or sell food such as milk, eggs, vegetables or other products. Women are forced to trade within the village or accept lower prices offered by male buyers from other areas.

(g) Loss of income, savings and employment
Loss in production, lack of storage and destruction of access roads result in assets (e.g. cattle) or products (e.g. milk) being sold at low prices. The selling price decreases while the shortage in supply induced by floods results in increased prices for essential goods. Moreover, floods and cyclones reduce employment opportunities, especially for women working in agricultural fields. As a result, there is a net loss in income which, in turn, leads to a loss in savings, thus making it even harder for households to cope with disasters.

10.3.2 Impacts on Special Vulnerable Groups (Poor Farmers) to Climate Change

There are many ways in which poverty and climate change are interconnected. Livelihoods of rural poor are predominantly based on natural resources. Poverty forces them to degrade their environment, which in turn reduces opportunity to enjoy services of these natural resources on a sustainable manner. Since climate change is likely to jeopardize the availability of natural resources base, poor people's livelihoods will face significant challenges in near future.

As revealed through the field experiences involving poor and marginal farmers, the key vulnerability contexts in relation to climate variability and change against each hydro-geophysical case are discussed below.

10.3.2.1 In Case of Cyclone and Storm Surge

Areas, which are covered for cyclone and storm surge most of the people, are found to be poor. Employment opportunities are extremely limited, which is why they remain poor. Land based production system consists of Aman production during Kharif season and Salt production on the same land during the dry season. The close proximity to the sea allow them to produce salt during November to early May. Since the lands are under salty condition for about 7 months a year, high salinity significantly reduces Aman yield from those lands. Although salt production requires labour and provides employment to a significant proportion of population in the island, employment opportunities drastically fall during the Aman season, since Aman production is not a very profitable venture.

10.3.2.2 In View Point of Salinity Intrusion

In the southwestern coastal region; an increase in salinity generally affects crop production, thereby poor and marginal farmers' vulnerability is directly linked with salinity ingress. Soil salinity above a threshold would reduce potential for the production of Boro, the most preferred crop in Rabi season. There are areas which are less saline at the initial cropping stages, become increasingly saline as Boro reaches reproductive stages in April. In such cases, adequate irrigation can still ensure a considerable harvest. However, under climate change and induced sea level rise effects, slightly saline areas will become moderate to highly saline and surface water based irrigation will not be possible. A combination of salinity and lack of adequate irrigation might result in a drastic reduction of crop production in the southwestern region of the country. At poor and marginal farmers' household level, reduced crop production will result in food insecurity. Poor farmers do believe that under climate change monga-affected areas will be extended to many other parts of the country.

10.3.2.3 In Case of Drought

Devastating and recurrent droughts caused by varying rainfall patterns occur frequently in many parts of Bangladesh, causing substantial damage and loss to agriculture and allied sectors. From field experience it appears that, rice, jute and other crops are usually greatly affected. Since rice production ensures micro-scale food security, drought comes as a curse to the poor and marginal farmers. Jute also suffers significantly because of lack of water for retting. Livestock also suffers, with many farmers having to sell their cattle at very low prices because they lack both fodder and drinking water.

10.3.2.4 In View Point of Flood

Bangladesh is known for its high vulnerability to floods of varied intensity. Flood occurs when rainfall runoff swells the rivers and overtops their banks. A prolonged flood can have catastrophic implications as it has been observed time and again in the recent past: the floods of 1988 and 1998 are considered to be catastrophic events, while the most recent flood of 2007 is also rated as a very high intensity flood that brought extreme human sufferings, colossal damages to agriculture and infrastructure and high costs on national economy.

A large number of people, especially the poor who live in low lying areas, take shelter in designated flood-shelters. It becomes a nightmare on the part of the authority to provide for various services: food, fuel, drinking water, primary health care, even physical security. In most cases, public institutions such as schools are transformed into flood shelters, while the academic activities suffer automatically.

10.4 Women's and Special Vulnerable Groups Current Coping Strategies

Bangladeshi people are familiar with climate induced hazards for a long time and as a result they have developed unique coping practices against such hazards. Since agriculture has a profound impact on the economy of the country, farmers always practice their self-innovative coping mechanism for survival. Millennia old traditional knowledge plays a significant role towards modifying and adjusting coping practices. As women are differently vulnerable than men under climate variability, they also have developed their own coping mechanisms. Many of their practices are needs-based, appear to be so obvious. However, these apparently "obvious" practices have all passed the true test of time and have contributed immensely to reduce their vulnerability against vagaries of nature. A few observed coping practices in relation to specific climate induced vulnerability have been discussed in this section.

Fig. 10.2 Increasing plinth level of house (*left*) and concrete plinth (*right*) using locally available materials

10.4.1 Coping Practices Among Women

The following are some of the micro-strategies used by poor women in Bangladesh to cope with frequent climate related disasters.

10.4.1.1 Avoidance or Prevention Strategies

People living in the disaster-prone areas of Bangladesh employ an array of measures to safeguard their lives and property against disasters. The majority of the people do have a clear understanding about the effectiveness of each of the preparedness measures, as well as their limitations. Often these measures do not help them because of the magnitude of disasters.

(a) Predicting and preparing for disasters
In the flood-prone areas, vulnerable people have used their own science and arts to predict floods. This traditional tool is becoming of little help, however, due to the changing nature of disasters, leaving the community with no choice but to rely on whatever early warning system is in place.
(b) Protecting houses and homesteads
Before the flood or cyclone season, families try to make their houses more resilient to disasters by reinforcing walls and roofs with locally available resources, increasing the plinth level of households (Fig. 10.2) and elevating the level of cow sheds. More financially secure households raise the level of tube wells.
(c) Storing essential items
Women preserve fuels, matches, dry food (such as rice, peas, puffed rice, flattened rice and molasses), ropes and medicine at home and prepare portable mud stoves for future use. Women often collect firewood to store in dry places for later use. They also collect and store safe drinking water during and post disaster period (Fig. 10.3) for the whole family.

Fig. 10.3 Reserve safe drinking water in the house

Women also store fodder for domestic animals, seeds, food, harvest, blankets and valuables on machas (high wood or bamboo structures for storage), which are also used to protect goats and poultry from flood water. Many women store cooking utensils, productive assets (i.e. ploughs, fishing nets) and other valuables under the soil to protect them from being washed away by cyclones.

(d) Teaching children
Educating the younger generations about how to protect themselves has been a key strategy employed by households living in disaster areas. Teaching life-saving skills such as swimming and understanding cyclone signals are examples of how parents prepare their children. No formal mechanism for teaching children disaster preparedness exists, however; children usually learn from family discussions or meal-time conversations. Various other activities such as animal rearing, grazing and taking part in plantation work with their parents, during which children have an opportunity to learn their parents' indigenous knowledge, are additional examples.

10.4.1.2 Managing Strategies

The managing coping strategies that followed by the women in the disaster prone areas are briefly described below:

(a) Safety of family members:
During disasters, women must constantly look after children, elderly and disabled family members, and animals to ensure their safety. In flood-prone areas, women prepare elevated platforms for family members with disabilities, using the *chouki* (traditional bed) and bamboo. Often, to ensure that young children remain safe and are not carried off by flood water, parents construct a "fence-in" to keep toddlers in one place.

(b) Ensuring food security:
Since most households are dependent on agriculture, flooding season is particularly threatening. In general, there is an overlap between flooding time and the crucial rice harvesting period. If a flood comes early in the monsoon season, it destroys the standing crop, which results in food shortages. Disasters also affect the local economy, which is vital for generating employment opportunities for non-farmers in both rural and urban areas.

When a household faces a food crisis during or after a disaster, women are responsible for adjusting household food consumption by changing the type of food eaten (instead of consuming rice, for example, they resort to alternate foodstuffs such as *kaisha* or *kolmi,* local vegetation,) or by consuming less. Various studies acknowledge that since women's work is closely related to agricultural production, family food and income generation, the burden of food shortage falls on them.

(c) Protecting assets:
When flood water reaches the level of the livestock shed, people no longer keep their animals at home. In some cases, they send their cattle to relatives. Some poor families try to sell livestock in an attempt to hold cash security, preparing against the possibility that regular income could be jeopardized.

(d) Household work:
Work load distribution within the family disproportionately affects women during a disaster. When husbands or male members become unemployed, daily work for women increases even more as they have to manage resources, feed the family and look after the elderly. In most cases, caretakers for people with disabilities are also female. However, new studies have also documented that work distribution is changing: a significant number of female participants mentioned how their husbands changed their usual habits during flooding; many cook at home or take care of children (Alam et al. 2007).

(e) Managing finance by borrowing credit, selling and mortgaging assets:
In order to meet household financial needs, assets such as livestock, poultry and boats are often sold. Selling other valuables, mortgaging, or borrowing against assets, or borrowing from neighbors are other common strategies for survival. Many women in rural areas are now part of microfinance organizations, using their memberships to access loans.

(f) Migration and alternative employment
In many cases, especially in FHHs, women migrate as an adaptation strategy. Migration for employment increases after disasters, when people move out of areas with job deficits in search of work. Female migration, mostly from FHHs, contributes a major share of the informal urban labor market. The major activities that employ women in urban areas include serving as domestic help, brick breaking, sewing, jute bag making, ash selling, fish and vegetable vending, selling rice cakes and working in the RMG industry. For earning, they sometimes compromise with their values and dignity (i.e. begging). Women who have alternative livelihood options prefer not to migrate as laborers; households that have boats, for example, earn incomes by ferrying people. Some even open small

shops on the boats. Selling advance labor for money is another common practice; farmers often view this as ensuring future employment, although it also makes for financial shortages in the future since they have already been paid.

10.4.1.3 Recovery Strategies

Rebuilding houses, re-stocking livestock, securing an income, repaying borrowed money, treating affected family members, and restoring other aspects of life such as children's education are all parts of recovery from disasters. In all of these activities, women are actively involved.

Besides these above-mentioned coping strategies, special vulnerable groups also practice the following types of strategies against different types of natural disasters.

10.4.2 Coping Practices Among Special Vulnerable Groups (Poor Farmers)

10.4.2.1 Coping with Cyclone

Coping with cyclone is generally related with the understanding of different signals and awareness. Issuance of cyclone forecast and warning are commonly practiced non structural coping measures towards reducing cyclone-related damages and losses. Taking shelter in the cyclone shelters is a common coping mechanism in Bangladesh though evacuation rate is not high due to lower capacity of cyclone shelters.

After 1971, another practice of taking shelter at the time of cyclone emerged as that people with their cattle take refuge in a land made highly raised. The inhabitants usually tie-up their houses in a strong manner so that these can withstand the severity of storms. They keep food, by digging earth, in pots made of mud. People use to keep seeds in polythene bags and keep those bags digging earth.

During post disaster phase people use to give efforts to rebuild their affected houses. In some cases they are compelled to take loans with high interest from the local mahajans just to meet their mere survival needs in an emergency.

10.4.2.2 Coping with Waterlogging

To cope with waterlogging people generally build houses with fences made of bamboo ("muli" bamboo) and wood. The foundation floors of the houses are raised so that water does not enter very easily, until it attains a certain level.

In the case of crop-agriculture, late varieties of "Aman" rice viz. "kazal-shail", "raje-shail" (both black and golden), "chapraish", "kartik-shail", "dholamota", "leiccha", "nazir-shail" are sown with a view to coping with water-logging. During the water-logging period cattle are reared/kept by raising the floor. Seed-beds are also prepared by raising the piece of land with soil/mud. In some places crop-land is raised to some extent for cultivating winter crops ("rabi" crops). In many areas as a precautionary and safety measure, the levees (sides) of the fishing ponds are raised up to a certain level so that fish cannot leave the ponds.

Ceiling-like raised/high platforms, locally termed as "Darma", are built inside the houses so as to keep ownership documents/deeds of lands, other important papers/documents, dry food e.g. fried swollen rice ("Cheera", "Muri" etc.), rice, and pulse, salt, sugar ("gur"), matches, candle, kerosene, quilt, "kantha", etc. safe and stored in the wake of emergency during the water-logged period. Rainwater is harvested/collected in some areas of the country with a view to using as drinking water since all tube-wells go under water during the waterlogged period. Besides this measure, wood/branches of trees are stored on "Darma" to be used as firewood for boiling pond-water. During the waterlogged/flood time, water is made purified by some families either by boiling or by using alum ("fitkiri"). But most of the people are not that much aware in Bangladesh. Ovens are made using mud, tin, and cement and kept on "Darma" in order to use during waterlogged period/flood time. Cooking is done on top of beds using those ovens, which the participants have learned from mimic demonstration/publicity performed in mass communication campaign.

10.4.2.3 Coping with Salinity

Bangladeshi rural people of saline prone region previously used drinking water from shallow tube-wells, when they did not have any specific knowledge about salinity. But now-a-days, with the dissemination of knowledge, they usually drink water from deep tube-wells since the chance of water being saline is much lower in the latter case. They used to drink water from ponds as well. Now even when people drink water from shallow tube-wells, they do purify it using alum ("fitkiri"). As a noticeable effect of salinity, the complexion of peoples' skin becomes darker. But people have been used to/adjusted to this phenomenon for being with it for a longer period of time. For cultivation, farmers use fertilizers viz. gypsum, TSP, potash, etc. to reduce salinity in land. The extent of salinity is different for different sections of an uneven land. Hence to make the extent of salinity equal all over the land the farmers first make the land even and then use various types of fertilizers mentioned above.

10.4.2.4 Coping with Drought

Since ancient times, farmers have practiced irrigation using surface water from nearby sources for a variety of crops including Aman and a number of nongrain rabi crops. There have been local Aman species/cultivars that require very low level of supplementary irrigation. Traditional irrigation techniques have been used extensively. The surface water systems of the country are largely dependent on upstream countries: India, Nepal, Bhutan and China. Increasing water withdrawal upstream and the diversion of water from the main transboundary courses reduced the flow in Bangladesh significantly during the dry months (Rahman et al. 1990; Halcrow and Associates 2001). Consequently the possibility of surface water irrigation in the country has been reduced considerably.

To maintain self sufficiency in food production, farmers have adapted to the use of modern irrigation techniques. Mechanized pumps have replaced the traditional methods of transferring water. Ground water irrigation involves high production costs, especially for the poor farmers engaged.

People cope with drought condition in different angle in different poverty level. Marginal people take risk if it rains they might get some production without irrigation. But rich farmer do cultivation with irrigation. Marginal people collect drinking water far away from their homes. It makes many social problems. Women have to take burden in their shoulder to collect safe drinking water from a long distance.

With the onset of drought, since lands become covered with a thin layer of salt farmers thoroughly plough their land upside down in order to reduce salinity. Since water becomes scarce and less available farmers bring water from ponds to use it in their lands for cultivation.

Farmers usually use pitchers for fetching water from nearby ponds to use for cultivation in lands. Relatively well-off farmers use shallow machines for channeling water from ponds. Throughout the drought period there arises crisis for drinking water since water cannot be withdrawn using shallow tube-wells. People have to look for deep tube-wells in nearby locality in their drive for drinking water.

10.4.2.5 Coping with Riverine Flood

Depending on the depth of flooding, farmers use a number of indigenous varieties of paddy and other crops that ensure subsistence for the whole year. A particular type of deep water paddy is still in use in very low lands, which can withstand any level of inundation and provide a certain minimum yield.

High intensity floods affect crop agriculture the most. In areas where the recession of flood waters occur late, farmers find no opportunity to begin paddy cultivation afresh due to unavailability of seedlings. People living in less flood prone areas make paddy seedbeds in prospect of marketing the seedlings in highly flooded areas following recession of water. By transplanting these seedlings, farmers in deep flooded areas maintain food security. In some areas, farmers resort to restructuring the usual cropping calendar suited for local hydro-climatic regime and use the remainder of the wet season for alternative crops requiring shorter period for the harvest. The official agricultural extension services and local-level non-government organizations provide various support services to facilitate flood-coping mechanisms.

10.4.2.6 Coping with Flash Flood

In the flash flood prone areas, farmers always have to cultivate crops with the fear of sudden flash flood. Aman is a variety which cannot be grown in the flash flood prone areas because of the hydro-geological formation of the soil. As a result Boro is the only suitable option for the farmers in such region. In these circumstances, 10th May is the ideal time for harvesting Boro paddy. But unfortunately late April and the first week of May are the most vulnerable period for severe storms as well as flash floods. And now if farmers keep the crops on the field till the first week of May, then there is great risk of crop damage. To overcome this uncertainty farmers now a days use a modified variety of Boro, for which early harvesting is possible (2nd or 3rd of May). Through this preponement of crop calendar, risk of flash flood related damages can be avoided to some extent.

Still there is risk that flash flood might occur in late April. To cope with this difficulty, many farmers of the flash flood prone areas in Bangladesh have adopted submergible embankment technology. Farmers use a special type of embankment which they call dwarf embankment. This is a low height earthen embankment which is submergible but can protect river water to come into the locality at least up to 10th of May. For this reason they can maintain their level of productivity. Also with proper operation and maintenance of the embankment, farmers make fish cultivation possible because the embankment also holds the water inside the locality. Through this unique coping mechanism of the farmers, Boro and fish cultivation both have become possible in the flash flood prone areas of Bangladesh.

10.4.2.7 Coping with Tidal Flood

People take some preparation before the season of cyclone gets start. Preparation again depends on their capacity to invest. Usually they use to tie the corners of their houses with strong ropes or still wires. To protect from rain they use to repair their ceiling almost every year. Especially those houses, walls made of mud and ceiling made of jute sticks or leaves are specially taken care of before rain comes or cyclone strikes. People who are very poor and do not even have that much to repair the house with minimal efforts, they use to take shelters in neighbor's house, adjacent schools, madrasa. During the devastating situation of water logging due to excessive rainfall cattle, chicken, ducks all get shelter under the same room where the family lives. Very few families have that luxury to keep a separate cattle house, which is locally called "Goal Ghar".

10.5 Conclusion and Recommendations

Climate change is not gender neutral, and gender is an important determinant in climate change mitigation and adaptation. As climate change tends to magnify existing inequalities, with gender inequality being one of the most pervasive, it has major impacts particularly on women. Women are likely to experience worsening inequalities of different magnitudes as a result of climate change impacts through their socially constructed roles, rights and responsibilities, and because they are often poorer. It is now widely acknowledged that negative effects of climate change affect women the most because they depend on natural resources and the environment for all their activities and the basic needs of their families (Diagne Gueye 2008).

Women's coping efforts are severely challenged by gender relationships and handicapped by power structure both within the household as well as within the community. Despite having provisions for inclusion of women representatives in (local) governance processes, gender relationship having a bias towards males does not allow women to meaningfully participate in any decision making fora, while lapses in good governance practices alienate women's voices further, leaving virtually no room to meaningfully contribute towards the reduction of their vulnerability. The patriarchal elements of vulnerability of women will further eliminate women's opportunity to overcome their vulnerability.

Women, entrapped in water world due to prolonged water logging appears to be the most vulnerable group compared to other vulnerability contexts of women in various known geophysical set ups. Salinity affected women are also extremely vulnerable. Carefully planned efforts must be made to push saline front towards the estuary—a long-term solution is provided in National Water Management Plan, which requires immediate attention and financing. Meanwhile, sustainable solutions to address salinity in drinking water must be sought and implemented. The State must facilitate to increase coverage of safe and non-saline water supply in the saline affected areas. The relevant national institutions must pay attention towards surveillance and monitoring of salinity and of women's health. In addition, public health care system needs to be strengthened in saline affected areas.

In cyclone prone areas, adequate number of new cyclone shelters need to be built on the basis of population density. Despite the recognition that the existing cyclone shelters have saved millions of lives already, new structures should be built on modified design having provisions for women: at least one separate toilet designated for women, preferably a separate floor for women, at least one room designated for pregnant and elderly women, a ramp to accommodate the needs of physically challenged and women with advanced stage of pregnancy, etc.

Since extent and duration of floods will only increase under climate change, a good coverage of multipurpose flood shelters in flood vulnerable areas needs to be established. Each of these structures must cater to the particular needs of women, as in the case of cyclone shelters. Instead of curative measures towards fighting against water borne diseases including diarrhea, efforts must be made to popularize alternative "preventive measures" to reduce the health cost of women and children—the major victims of such diseases.

Women's resilience building demands women's empowerment in all aspects of life: physical and mental, social, economical, political, and cultural. The State must assume responsibility to remove common and known barriers towards empowering women. Special attention is also required to ensure that similar barriers for other disadvantaged groups are removed with needs-based targeted programmes and practices.

Though it appears obvious that simple coping would not help women much to reduce their vulnerability, raising awareness regarding the anticipated elements of risks and early warning could facilitate them to strengthen their approaches to coping. However, such programmes must be tailor-made to cater the needs of the target audience—the women and the disadvantaged.

10.5.1 Recommendations

Some specific and general recommendations have been drawn in line with the above findings and discussions on women and climate change issues. It is the prime task to promote women's empowerment through capacity-building before, during and after climate-related disasters, as well as their active involvement in disaster anticipation, early warning and prevention as part of their resilience building. The possible way to ensure women's empowerment through creating space for women and active involvement in disaster related activities and decision making and access to services with the help of government and NGO initiatives. Household head especially husband can take the lead to encourage women to take part such type of activities. In addition, it is necessary to encourage the women's movement to take full responsibility and ownership of the gender and climate change discourse to ensure that implementation of UNFCCC and Kyoto Protocol (and post-KP) measures take their specific concerns into account (Mensah-Kutin 2008). Furthermore, support and promote practical solutions to enhance women's adaptive capacity and livelihoods including alternative agricultural practices, equitable employment opportunities, access to credit, labor-saving technologies and equipment, safe shelter and facilities, energy and water supplies and services (Diagne Gueye 2008) and set up adaptation funds, according to principles of democratic governance and civil society participation to play a key role in promoting women's rights and to prioritize poor women's needs. Safety net program for poor women and children needs to be strengthened through subsidy provided by the government and international agencies with active involvement of village leader. Not last but least, gender issue is not only women issue. Gender equality can only be done with proper and balanced participation of men and women (Takeuchi and Shaw 2009).

Acknowledgements The first author gratefully acknowledges the support from the Japan Society for the Promotion of Science (JSPS) of Japan for conducting this research. The second author specially thanks for her support from the GCOE-ARS postdoctoral program of Kyoto University.

References

ADB (2004) Country briefing paper on women in Bangladesh. Asian Development Bank

Aguilar L (2004) Climate change and disaster mitigation. Available on-line: http://www.iucn.org/congress/women/climate.pdf

Alam K et al (2007) Drowning sand and the Holy Banana Tree. Handicap International, Dhaka

Halcrow and Associates (2001) Options for the Ganges dependent area. Draft Final Report: Main Report. Sir William Halcrow and Associates, for Water Resources Planning Organization (WARPO), Ministry of Water Resources (MOWR), Government of the People's Republic of Bangladesh, Dhaka, p 332
Baten MA, Khan NA (2010) Gender issue in climate change discourse: theory versus reality. Unnayan Onneshan-The Innovators, Dhaka
BBS (2001) Statistical year book of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, Government of Bangladesh, Dhaka
Cohen MF (2006) The condition of women in developing and developed countries. Independent Rev XI(2):261–274, ISSN 1086-1653
CPD (2001) Bangladesh facing the challenges of globalization: a review of Bangladesh's development. Centre for Policy Dialogue (CPD), Dhaka
CPD (2004) Coastal newsletter on reducing vulnerability to climate change through awareness, action and advocacy. CPD, Dhaka
Diagne Gueye Y (2008) Genre, Changements Climatiques et Sécurité Humaine: le cas du Sénégal. ENDA Programme Energie, Dakar
Enarson E, Hearn Morrow B (eds) (1998) The gendered terrain of disaster: through women's eyes. Praeger, Westport
GTZ (2005) In: Schmidt A, Bloemertz L, Macamo E (eds) Linking poverty reduction and disaster risk management. GTZ, Bonn, p 88
Ikeda K (1995) Gender differences in human loss and vulnerability in natural disaster: a case study from Bangladesh. Indian J Gender Stud 2:171–193
IPCC (2001) Climate change 2001: impacts, adaptation and vulnerability, Summary for policymakers. Working Group II, Inter-governmental Panel on Climate Change (IPCC), Geneva
Irene D, Khurshid A, Wahida BA, Diagne Gueye Y, Naureen F, Mensah-Kutin R (2008) Gender, climate change and human security lessons from Bangladesh, Ghana and Senegal.
Grossman A, Owren C (eds). The Women's Environment and Development Organization (WEDO) with ABANTU for Development in Ghana, ActionAid Bangladesh and ENDA in Senegal. Available at. http://www.wedo.org/wp-content/uploads/hsn-study-final-may-20-2008.pdf
Mensah-Kutin R (2008) Decentralisation and women's rights in Ghana: issues, gaps and options. Paper presented during an IDRC Workshop on Decentralisation and Women's Rights in sub-Sahara Africa, Dakar, 21–22 January 2008
Peterson K (2007) Reaching out to women when disaster strikes. Soroptimist white paper, Soroptimist international of the Americas, Philadelphia. Available online at: http://www.soroptimist.org/whitepapers/wp_disaster.html
Rahman AA, Huq S, Conway GR (1990) Environmental aspects of surface water systems of Bangladesh: an introduction. In: Rahman AA, Huq S, Conway GR (eds) Environmental aspects of surface water systems of Bangladesh. University Press Ltd, Dhaka
Takeuchi Y, Shaw R (2009) Gender dimension in risk communication: a perspective from sediment disaster in Hiroshima, Japan, in RDD Special Volume Gender and Disaster, 30:63–75, UNCRD Press
UNDP (2002) Human development report of South-Asia. Oxford University Press, New York
UNDP (2009) Resource guide on gender and climate change. UNDP, New York
UNEP (2005) Mainstreaming gender in environmental assessment and early warning. UNEP, Nairobi
World Bank (1999) The world development report-1998/99. World Bank, Washington, DC

Part IV
Adaptive Actions

Chapter 11
Agriculture Adaptation in Haor Basin

Abu Sumon and Aminul Islam

Abstract This chapter attempts to capture the dynamics of hydrological regime and agricultural adaptation issues in the face of changing climate and its variability in the context of the wetland ecosystem locally known as *haor*. Since haor basin is geographically located at the foothill of Assam and Meghalaya is subject to high risk being hinterland of the highest rainfall zone globally. Climate change has created two prong adverse impacts particularly on agricultural cycle as damage risk increased at the beginning of seeding stage if land is not water free due to late monsoon rain and at the harvesting time early flash flood in pre-monsoon. The changing trend of climate induced hydrological regime associated with variability in the pattern and severity of rainfall triggering early and irregular flash flood in haor basin. Study finding reveals the fact that such risk in agricultural sector is increasing significantly as available days for cultivation is reduced on an average by 10–15 days compared to 30 years back, while the high yielding rice varieties cultivated at present are of longer duration compared to the local varieties. In response to this changed hydrological regime, farmers need to adapt with quick growing, diversified climate resilient cropping pattern and new adaptive technologies. Particularly, need of the time is to adapt with short duration rice variety along with high value quick growing horticulture and alternative inter cropping approach as a risk proof measures. Cropping on floating beds is found potential to create opportunity of double cropping in a single year, which would increase the livelihood opportunity for farmers in haor areas. Strategic development intervention for haor area aimed at transformational change should consider (a) climate and disaster resilient water management including advanced early warning system linked to remote vulnerable communities; (b) de-leasing haor ecosystem and ensure establishment of fish sanctuary at the dry

A. Sumon (✉)
Community Based Adaptation Programme, UNDP-GEF, Dhaka, Bangladesh
e-mail: abu.sumon@gmail.com

A. Islam
United Nations Development Programme, Dhaka, Bangladesh

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*,
Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_11, © Springer Japan 2013

season water body; (c) declare study based delineated area suitable for common pool resources (CPR) to be managed by the poor and marginalized people based on key principles of wise use of natural resources and improve ecosystem services; and (d) agricultural development including adaptive diversified crop and horticulture, development of fisheries and livestock for food security. Accessibility, availability and entitlement security of the poor haor community could be arranged through broad based engagement in participatory planning and management system as well as ownership in development initiatives.

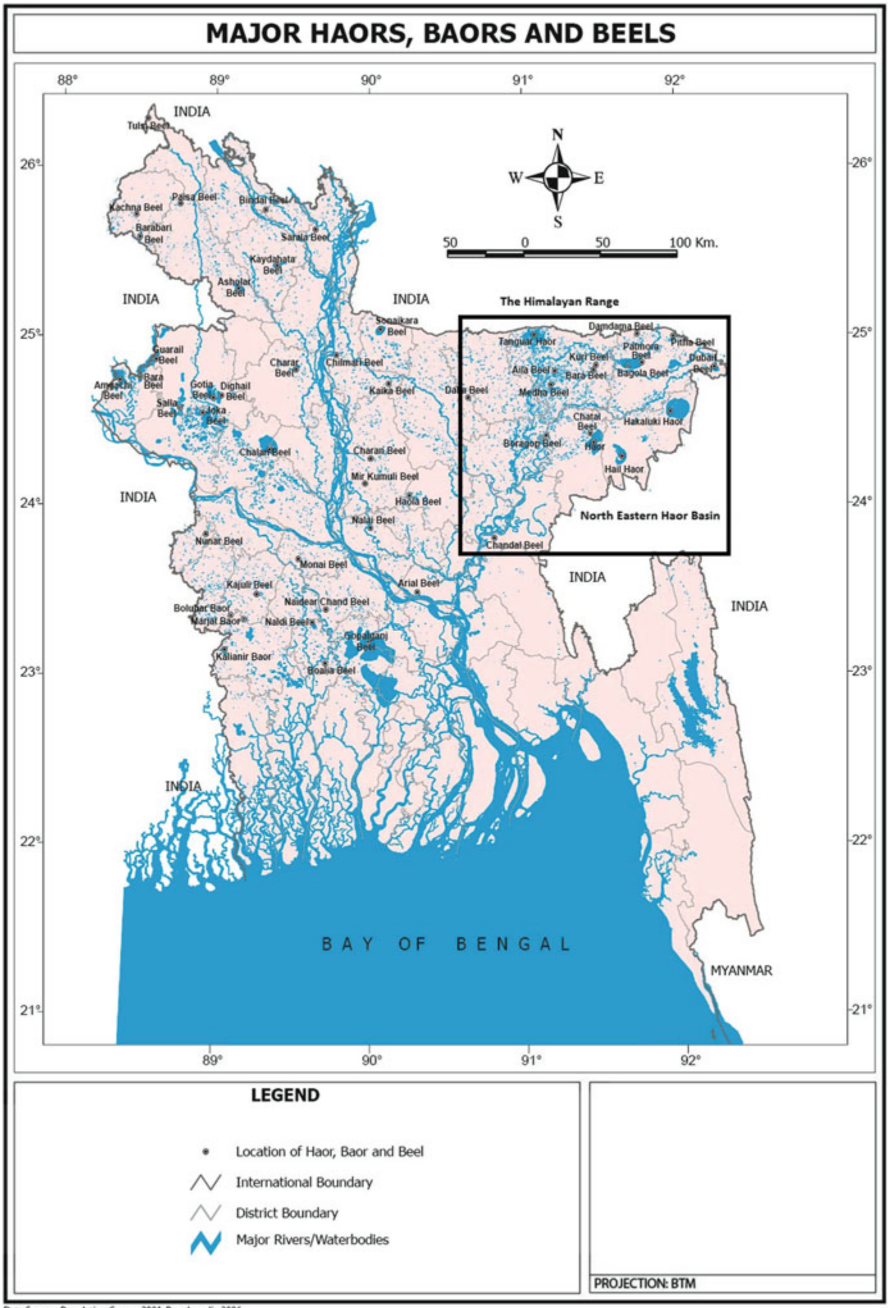
Keywords Agriculture adaptation • Climate change • Common pool resources • Community participation • Haor basin

11.1 Introduction

A ***haor*** is a local term for wetland ecosystem in the north eastern part of Bangladesh which is physically a bowl or saucer shaped shallow depression, also known as a backswamp. *Haors* are flooded every year by the monsoon floods, and most of them retain some water throughout the dry season. This wetland system supports high biodiversity, an attractive habitat for migratory birds, provides ecosystem services such as flood storage; nutrient cycling/storage and related pollution control, storage of ground water and recharge. It's a good habitat for fish, aquatic flora and fauna and wildlife as well. All these together make it a landscape of aesthetic value with great opportunities for livelihood and agriculture. In a country where one third of all area can be termed as wetlands, the haor[1] basin is an important wetland ecosystem (Fig. 11.1), which accounts for 13.5 % of the country's total area, 12 % of the population and 11 % of agricultural households. This wetland ecosystem is spread over seven districts such as Sunamgang, Moulvibazar, Sylhet, Habiganj, Kishoregang, Netrokonam and Brahmanbaria districts. The total area of Haor-type wetland ecosystem in Bangladesh is 8.5 million hectares. The haor basin is bounded by the hill ranges of India–Meghalaya on the north, Tripura and Mizoram on the south, and Assam and Manipur on the east. The basin extends north to the foot of the Garo and Khasia Hills, and east along the upper Surma Valley to the Indian border. There are other types of wetland such as "baor" (oxbow lake) and wetland of smaller in size widely distributed are locally known as "beel".

The Haors in Bangladesh are subjected to frequent flash flooding causing extensive damage to crop, life and properties (Table 11.1). Flash flood means rapid flooding of geomorphic low lying areas—washes, rivers and streams—caused by the intense rainfall associated with a thunderstorm, or multiple thunderstorms. Flash floods are distinguished from a regular flood by a timescale less than 6 h.

[1] A haor is a wetland ecosystem in the north-eastern part of Bangladesh which physically is a bowl or saucer shaped shallow depression also known as a back swamp.



Data Source : Population Census 2001, Banglapedia 2006

Fig. 11.1 Location of Haor basin and Wetlands by types in Bangladesh

Table 11.1 Area of the Haor basin

District	Total area in ha	Haor area in ha	No. of haors
Sunamganj	367,000	268,531	95
Sylhet	349,000	189,909	105
Habiganj	263,700	109,514	14
Maulvibazaar	279,900	47,602	3
Netrakona	274,400	79,345	52
Kishoreganj	273,100	133,943	97
Brahmanbaria	192,700	29,616	7
Total	1,999,800	858,460	373

Flash flooding occurs when the ground becomes saturated with water that has fallen too quickly to be absorbed. The runoff collects in low-lying areas and rapidly flows downhill. Flash floods most often occur in normally dry areas that have recently received precipitation, but may be seen anywhere downstream from the source of the precipitation—even dozens of miles from the source.

In haor area 29.56 % of the population lives below the Lower Poverty Level (LPL), which is slightly lower than the national average of 29.26 %. Out of the seven haor districts, poverty incidence is the worst in Kishoreganj and Netrakona districts while in other districts it lies within a 5 % deviation range. Employment potential is generally expressed as the participation rate (%) of the number of economically active population above age 15. At present 61.84 % of the economically active population in the haor area can serve in the labourforce, which is higher than the national average (58.74 %).

Currently, 28.5 % of the population of the haor area is not engaged in any kind of employment. Compared to the national figure of 14 %, only 3 % of the haor population has no cultivable land. On the other hand, 81 % of non-farm holdings have no cultivable land, which is higher than the national average (74 %). In the farm holding category, 34 % of farm households are marginal, which is 5 % below the national average. Similarly 51 % of the farm households in haor areas are small farmers while the national figure is 49.5 %.

11.2 Agriculture in the Haor Region

Land use pattern reveals the fact that almost 65 % of the haor area used for agricultural purpose (Table 11.2). However, most of this agricultural land remains under water during monsoon. Biodiversity is rich here because of these land and water interface over time. Land is available for agriculture for 5–7 months subject to early flash flood occurrence.

The major occupation of the haor districts is agriculture. Half of the population (53.67 %) depends on agriculture for their subsistence. There is a remarkable

Table 11.2 Land use pattern of the Haor areas

Land type	2010 Area (ha)	2010 Area in %	2021 Area (ha)	2021 Area in %	2030 Area (ha)	2030 Area in %
Agriculture land	1,310,945	65.55	1,263,750	63.19	1,217,390	60.88
Settlement (homestead, pond and Road)	372,413	18.62	419,608	20.98	465,968	23.30
Hill	133,417	6.67	133,417	6.67	133,417	6.67
Forest (excluding hill forest)	66,345	3.32	66,345	3.32	66,345	3.32
Perennial waterbodies	48,360	2.42	48,360	2.42	48,360	2.42
River	41,872	2.09	41,872	2.09	41,872	2.09
Canal/Khal	26,448	1.32	26,448	1.32	26,448	1.32
Total	1,999,800	100.00	1,999,800	100.00	1,999,800	100.00

variation in the occupation of the haor population. A large portion of the population earns their livelihood from business (12.52 %) followed by non-agricultural labour (6.13 %), service (5.65 %), fishery (2.59 %), and transport (2.39 %). A significant part of the population (3.41 %), especially in Sylhet (10.32 %), Maulvibazaar (4.64 %) and Brahmanbaria (4.56 %) depends on remittances coming from home and abroad. About 52 % of households own agricultural land. The tenure pattern of the households depends on the prevailing practices of land use and crop cultivation. There are three types of tenure groups in the area such as tenant, owner and owner-cum-tenant. About 68 % are landowners and 25 % are owner-cum-tenant. Landowners either cultivate their land themselves or/and have them cultivated by hired laborers. The owner-cum-tenant cultivates land of other people along with their own land while tenant farmers (7 %) cultivate land belonging to others only (CEGIS 2012).

In Haor areas, three major resources viz. land; water and human (CEGIS 2012; CNRS-ActionAid Bangladesh 2008; CNRS 2007; Climate Change Cell 2008; Bangladesh Haor and Wetland Development Board 2012) resource could not be utilized in an integrated way due to its unique geographical as well as complex hydrological characteristics. Some of the important aspects to utilize the resource are to ensure harvesting of principal crop (Boro[2]), enhancement of communication net works, multiple uses of water resources with emphasis on fishery, agriculture, cattle farming and employment opportunities for both men and women throughout the year. The flood control infrastructures in these districts have been damaged by recurrent flash floods requiring immediate repair and rehabilitation. Boro rice in these areas were damaged and will continue to be damaged till such time if

[2]The boro rice is commonly known as winter rice. The term boro is Bengali originated from the Sanskrit word "Boro" which refers to a cultivation from November to May under irrigated condition.

arrangements for protecting them from early flash floods are not made. Boro being the only crop grown in the area during the year, the repair and rehabilitation work are ought to be the primary concern to check starvation due to repeated damage of the only crop through recurring early flash floods almost every year.

The productivity of this wetland has contributed to a food surplus in this region, and may believe that there is a potentiality for further increases of land for agriculture purposes. However, change of flood timing and pattern is probably one of the main reasons for changing local ecosystem and the livelihood of the local people. Flashflood causes crop damage that is considered as a big threat to the people, especially who work as sharecroppers or landless laborers. Sometimes, the flashflood comes early, just before the rice harvesting and during that time the people of haor basin, do not even get the time to harvest their crops. In many cases, it has been found that this part of Bangladesh losses 100 % of its crops. Threats to local livelihoods are not solely confined to wet season catastrophes. During the dry season, the water-covered area gets reduced by significant amount and turns individual small water bodies called beels and kuas as well as lakes and canals. These separated water bodies are vital for breeding and maintaining stocks of fish.

The hydrological regime of the haor basin has changed over years. The main effect of the changed hydrological regime in haor agriculture is that farmers get 10–15 days less for cultivation than 30 years back, again the high yielding rice varieties cultivated at present are of longer duration compared to the local varieties, predominantly cultivated earlier. To cope with the changed hydrological regime, farmers need to adapt diversified cropping pattern and new technologies. Adapt short duration rice variety for saving their only one crop from flash flood. The constrains of boro rice cultivation and important characteristics of rice varieties viz. short growth duration, relatively tall, lodging tolerance and non-shattering habits need to be identified. Another coping strategy could be cultivation of tall Aman variety or vegetable on floating beds (Baira) near the villages. There are many other cereal, vegetable, spices, pulses and tuber crops those could be cultivated successfully during rabi season in the haor basin and could be harvested much earlier than boro rice which could avoid flash flood. Cropping on floating beds (Baira) is found potential to create opportunity of double cropping in a single year, which would increase the livelihood opportunity for farmers in haor areas.

Onrush water caused by rainfalls in upper catchment in Meghalaya, India during March and April resulted flashfloods in Haor areas. It is evident that rainfalls in Meghalaya in March has been increased from average 150 to 250 mm. Erratic behavior of rainfalls intensifies the severity of flashfloods in the haor areas. It is experienced that the risk of the hazard to damage winter rice is increasing. Therefore, introduction of alternative cropping practice and short duration rice varieties can be the right solution of the problem as a climate change adaptation measure.

Almost 20 % of the land in haor areas is comparatively raised land known as kanda. Haor people are dependent on surface water irrigation for winter rice cultivation and kanda lands are found not suitable for rice cultivation. In most of the cases, kanda lands are remain fallow. Research results owed that kanda lands are suitable for rabi crops viz. pulses, seed oils and vegetables which require very minimum irrigation water. These crops are more profitable than that of rice. Most of the kanda lands are owned by the government, therefore, these lands can be distributed among the landless households along with technological and input support. But it is also important to keep in mind that there are some other uses of kanda lands viz. grazing land, crop processing, seedbed, and playground. Historically these lands were characterized by either reed lands or swamp forest. Therefore, ecological phenomenon of the kanda lands should also be taken care off.

Most popular rice variety among the farmer of haor areas is BRRI dhan 29. As per the research findings, it requires a total of 163 days to grow. Production of BRRI dhan 29 is found 6.18 ton/ha in the research plots. On the other hand, research tested a trial variety advanced by BRRI[3] called BRRI dhan 45 in the haor areas. It requires 139 days to grow and production is 5.98 ton/ha. Though the production of BRRI dhan 45 is a bit low than that of BRRI dhan 29 but BRRI dhan 45 can be harvested 24 days ahead and that can reduce risk of damage by flashfloods substantially. Therefore, BRRI dhan 45 can be released for haor areas. DAE[4] can take the role in this regard.

The haor region has long been lagging behind mainstream national development although the economic development of Bangladesh is moving steadily at a moderate pace. Although the contribution of the haor region has been on average around 6-8 % of the national GDP. Considering the regional growth, the current GDP contribution of the haor region in the base year is 263 billion, which is 6 % of the total GDP of the country. Of this 36 % is from the agriculture sector, 27 % from the industrial sector and 37 % from the service sector. The annual average growth rate of GDP of the haor region is 5 % whereas the national average is 6.1 %. The government has taken many initiatives including the preparation of national and regional strategies to steer economic growth and has accordingly prepared plans over the years to boost the country's development. It is difficult to foresee the country's overall progress without the development of the haor region as it covers a major part of the country and population that deserves special development initiatives. The future challenges in the context of climate change are also a major concern for the sustainable development of the region (Fig. 11.2).

11.3 Accessing Kanda[5] Lands by the Landless Poor

Access to the kanda lands to the landless households living in the haor region will lift themselves out of extreme poverty. Agriculture here is highly susceptible to climate variability, especially flash floods. Crops can only be grown in the dry

[3] BRRI is a major component of the National Agricultural Research System (NARS) of Bangladesh, dealing with research and development in relation to rice production, the staple food for our people.

[4] The Department of Agricultural Extension (DAE) is the largest extension service provider in Bangladesh, and has considerable human and financial resources.

[5] The outer portion of the haor adjacent to the surrounding villages is known as kanda. This land is government land with no private claims on it.

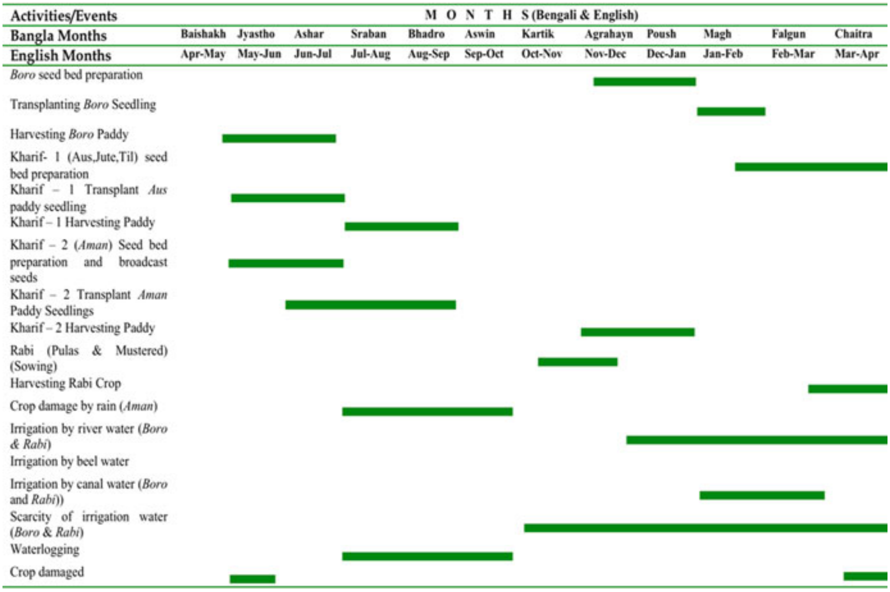


Fig. 11.2 Farming calendar in the Haor

season and even then are vulnerable at harvest time. Overall a fifth of land is *kanda* (slightly higher lands) which are traditionally not cultivated because surface irrigation of rice (the dominant crop in the area, with its high water demand) is not possible there. Most kanda lands are public or *khas* lands. Here monsoon water recedes first and they are inundated last. Access to these lands will enable the extreme poor to get a return from otherwise unused kanda land using climate resilient farming practices and through group initiatives to improve access to local services.

Haors are one of the most poverty prone areas in Bangladesh because the land is single cropped (mainly the rice) and often that crop is damaged by flash floods. The severity of flash floods increased during 1997–2006 which is consistent with increases in rainfall in the upper catchments of Megahalaya in India in the last 30 years (source: Indian Meteorological Department). Moreover, unusual cold waves and drought also damage rice crops. About 20 million people's livelihoods are dependent on haor resources. Over half live below the poverty level of whom about 3.5 million people live in extreme poverty (direct calorie Intake (DCI)—16 % and cost of basic needs (CBN)—35 %). Thus more than 10 % of haor area people live in extreme poverty. The bottom 10 % include female headed households, elderly people with no family support, households with disabled members, and large families dependent on a single earner(CNRS-Action Aid Bangladesh 2008).

One fifth of haor land is *kanda*—slightly higher lands that are not cultivated and are typically public lands treated as commons. Therefore, it is assumed that there are about 500,000 ha of kanda land in the haors. During resource mapping it was found that over 95 % of kandalands are owned by the Government. If the government plants to transfer 50 decimals (0.5 acres, 0.2 ha) of land to each extreme poor household, it is estimated that only 8 % of kanda lands (40,000 ha) will be needed to support the bottom 10 % (200,000) extreme poor households in is region (CNRS 2007). Kanda lands are traditionally not cultivated because:

1. They are slightly higher so monsoon water recedes first during November and they are inundated last (June),
2. Traditionally, people grow only rice in low lying areas (where water recedes in December and inundated in April/May),
3. Haor farmers are dependent on the natural irrigation using gravity flow of surface water,
4. The ground water table of haor area is over 700 ft deep so it is not feasible or cost effective to irrigate with tubewells,
5. About 60 years back, most of kanda lands were covered by reed lands and swamp forest and could not be farmed,
6. Existing crop lands in the haors need very little effort for land preparation, but this requires a very high effort in kanda.

Some adaptation research has already identified positive opportunities for kanda farming (Climate Change Cell 2008). It identified some crop varieties appropriate for kanda farming which need less irrigation water. It also found that kandas near rivers/canals could grow rice of certain varieties and could be irrigated by using LLP (low lift pump). Even in some places two crops could be grown if the area is free from risk of flash floods. We also identified low cost specialized tractors for land preparation (traditional cattle based land preparation is not possible in kanda), and ways of managing weeds and integrated pest management (IPM) techniques to cope with high pest levels. Using this cultivation package a return of Tk. 24,000 can be earned from 50 dec of kanda lands. Therefore, transfer these lands to the extreme poor along with technological and input support can help extreme poor people get out from the income poverty trap.

But solving income poverty cannot always lift a household from extreme poverty if they are not provided support for social protection, vulnerability reduction, empowerment, and wider opportunities. Therefore they need some safety net protection measure. A safety net system and crisis coping mechanisms for participants will be established so that extreme poor households can be supported if they faces any shocks (natural or physical). By addressing income poverty along with social support, this initiative will probably lift extreme poor households out of the poverty trap.

The north-eastern haor basin is one of three high poverty incidence regions in Bangladesh identified in World Food Program poverty mapping and World Bank and Government of Bangladesh assessments. Parts of seven districts fall in the haor basin. Sunamganj is the only district where all of its upazilas are considered to be in the haor environment. The district has experienced major damage of crop by flash floods in 6 out of 10 years (1997–2006). Seasonal migration rate is very high in these upazilas. The major problems in the area in regard to extreme poverty are:

1. The whole area remains inundated for about 7–8 months during the monsoon,
2. There are no economic activities during the monsoon and no other local employment opportunities resulting in high seasonal migration,

3. Fishing is controlled by lease holders, therefore, poor people cannot fish in the haors,
4. Only one crop (winter rice) and be grown and it is highly susceptible to flash floods,
5. Road communication is virtually absent along with public services,
6. Traditional NGO-based micro credit programmes are lacking and there are almost no development projects or NGO activities in the remote villages,
7. Serious social problems (polygamy, gender discrimination, water-sanitation, primary education, health issues),
8. High variability in the climate (cold wave, drought, hail storms, wave erosion, flash floods).

The proposed initiative is highly relevant to addressing needs of the area and target people. It will diversify crops away from monoculture of winter rice into crops that are less susceptible to damage by flash floods. It will bring support for the poor to villages lacking NGO projects and government service provision. Awareness raising and bringing service providers to the area will start the slow process of addressing the serious social problems noted above. The innovation itself and community risk mitigation planning and coping provisions will help reduce the impact of climate variability.

The proposed initiative should target extremely vulnerable households for the transfer of kanda lands. These households have no crop land, and therefore are completely dependent on manual labour and collection of haor resources including wild food, fodder, thatching materials, grasses, fuel-wood, fish, birds, etc. This initiative should facilitate transferring small areas of unused public lands to the extreme poor along with input and technical support. The initiative should enable participating households to earn a good income from this land. Most of the crops to be grown on kanda lands will be harvested before the occurrence of flash floods. At least one adult woman from each household should be involved in adaptive farming and women-friendly crop packages should be offered. Thrift groups with women should be formed. The savings gradually built up should be used for internal lending among women members once confidence develops. Demand for other services should be created among the extreme poor and they should be linked with service providers.

This particular innovation has been proposed because it will have a very tangible output and the innovation arises from research findings that have been tested in subsequent years and found successful. During the research and testing phase Bangladesh Rice Research Institute, Bangladesh Agricultural Research Institute and Department of Agriculture Extension were involved. This will bring quick benefits to the participants and can be scaled up in the whole haor area. The extremely vulnerable households in the area are basically landless farmers and farm labourers, traditionally they are involved in farming so they can easily combine their existing skills and expectations with new techniques provided by the project.

The objective of the proposed initiative is to lift the targeted households from extreme poverty through crop diversification, ensure food security and promote adoption of climate resilient farming practices in haor areas. The changes that are expected out of the proposed initiative: (a) fallow kanda lands will be converted to

Table 11.3 Risks and mitigation strategy

Risk	Government delay in transferring government land (*khas kanda*) to the hardcore poor or brought under Common Pool Resource (CPR) Management by the poor based on wise use principle
Mitigation/ contingency	• Presently the khaskandas remain fallow and so the local consensus is likely to be to use these lands for agriculture • Taking a 1 year lease (*eksonabondobosto)* is a comparatively easy process • The first yearlong lease will be taken on behalf of the project participants • These lands have been unused for long therefore any lease cost will be very nominal • Once someone gets the possession of land and pays taxes against it, they have cultural, traditional and official rights to use of that land
Risk	• Poor may be excluded from kanda lands when cultivation is profitable
Detail	• Access rights of the poor are currently based on 1-year leases. Once local rich and influential see that the lands can be profitable, they may take possession
Mitigation/ contingency	• According to the law, the first leaseholder has priority to renew the lease and participants will be made aware of this and helped to renew access • Brought under CPR management with some key principles which benefits the nature as well as the poor people • Local level consultation and consensus building workshops will work to encourage the rich and influential to support the poor in this endeavour • This will be further mitigated by the fact (and its dissemination) that only 8 % of all kanda lands will be used, leaving plenty of lands for other users
Risk	• Single-crop farming is vulnerable to unexpected climatic conditions
Detail	• Climatic hazards hamper production of certain types of crops, e.g. prolonged fog may adversely affect potato production and cold waves or droughts may hamper rice. Farmers that rely on one crop are at higher risk
Mitigation/ contingency	• Each participating farmer will be given a package of a combination of crops and horticulture. Livestock raring is another option may be promoted • Each participating farmer will be trained on growing and advantages of diverse crops and horticulture
Risk	• Farmers may be reluctant to try non-traditional crops
Detail	• Farmers have relied on and have knowledge about traditional crops for years. They are likely to be change-resistant as they will not be sure there is a market for new crops or have the expertise of how to grow them
Mitigation/ contingency	• Traditional crops which can be stored for a long time will be promoted, such as sweet gourd, oil seeds and pulses • Demonstration of crop and horticulture farms which show proven results of more profitable and gainful over the traditional crops and horticulture • Local human resources will be trained for marketing support
Risk	• Quality seed of non-traditional crops may be scarce in the Haor area
Mitigation/ contingency	• A memorandum of agreement will be signed with BARI to supply quality seed • Local human resources will be trained for seed trading

productive farm lands, (b) the income of extreme poor households should increase, (c) consumption and diversity of food by extreme poor households will increase, (d) hygiene practices will improve, (e) a local market for non-traditional crops will form, (f) local entrepreneurs and resource persons will be developed, (g) demand for services among the ultra poor will increase, (h) the position of women in the family and society will improve (Table 11.3).

11.4 Innovative Farming Practices in the Haor Region

Several action researches conducted by different projects and NGOs has shown a wide range of option that may be suitable for the region with high flash flood vulnerability and dry season irrigation scarcity. Notably the research undertaken by Climate Change Cell in 2009 has presented a selection of crops that has performed well partnering with BRRI, BARI, and CNRS[6] in Jamalganj Upazila, Sunamganj District. Adaptive cropping has been tested at the farmers' fields demonstrated encouraging results. Two varieties of winter rice with higher yields attained maturity by end of first week of April have high potential to avoid flashflood risks. Over a dozen of vegetables and spice crops performed satisfactorily and proofed highly profitable compared to rice can be harvested at least a month before the current timing of flashfloods. Research findings have opened up avenues for the farmers to adapt to the risks of flashfloods. However, more social and institutional work is needed to sensitize farmers to make a shift from their traditional preference over rice to other non-rice crops as well as for an enabling institutional mechanism that could facilitate extension of adaptive cropping to wider communities in Bangladesh exposed to flashflood hazards.

Participatory land use survey was undertaken to identify the existing land use pattern of the haor areas. The survey was taken place on the basis of mouza as a primary unit and use of all plots of the mouza has been identified. PLUS was conducted in five mouzas in Jamalganjupazila which are Kandarbapur, Gongadharpu, Chhoyhara, Latifpur and Chanpur, Survey information revealed that about half of the mouza are not under cultivation. Haor dwellers are mainly dependent on surface water for winter rice and kanda lands (a bit raised land) are found not suitable for rice cultivation (due to irrigation problem) remain fallow. As per the land use survey, about 20 % of total lands are kanda, which are remain fallow or under used for grazing land, seedbed, playground and crop processing area. Chart reveals that 53 % of total mouza area is not used for agriculture purposes. Land use pattern of Chhoyharamouza shows that total agricultural land in the mouza is about 53 ha while area of kanda is about 55 ha. These kanda land remains fallow but potential for rabi crops (spices, vegetable and pulses).

Rice is the main crop of the haorbasin which is very widely cultivated by the local farmers (Table 11.4). A previous study revealed that almost 90 % of the land used for rice cultivation (CNRS 2001).[7]

Crops (especially rice) are used to damage by the Flash flood is the main Climate Change challenge in the haor area. As a result, adaptation of new short duration variety rice was found very important for the ensuring the livelihood of the people

[6]Center for Natural Resource Studies (CNRS) is a national level NGO focuses on ecological management of floodplain ecosystem through community-based management approaches in Bangladesh.

[7]CNRS (2001): Integrated floodplain management—land water Interface. Unpublished project report.

Table 11.4 Comparative advantages of different rice varieties

Plot no.	Date of sowing	Date of transplant	Date of harvest	Crop's life span (days)
BRRI dhan 28	18.11.06	25.12.07	15.04.07	147
BRRI dhan 45	22.11.06	25.12.07	10.04.07	139
CH 45	18.11.06	25.12.07	12.04.07	145
Hobiganj boro 6	18.11.06	25.12.07	12.04.07	151
BRRI dhan 29 (traditional practice)	18.11.06	24.12.07	30.04.07	163
BRRI dhan 29 (new technology adopted under the project)	4.12.06	24.12.07	30.04.07	149

Table 11.5 Lifespan of different pulse crop variety

SI no.	Name of crops	Date of sowing	Date of harvesting	Crop's lifespan (day)
1	Mungbean	05.12.06	14.04.07	129
2	Lentil	05.12.06	17.03.07	102

of this area. A total of six different types of rice varieties were tested. Among those some new varieties e.g. CH 45, BRRI Dhan 45 which are not yet released by the BRRI as variety were tested while some old and popular HYVs were tested adopting different methods to reduce duration of life cycle. BRRI dhan 29 (new technology) is a long duration variety, and mostly popular in haor region. Its life duration has been manipulated by crop management and resulted reduction of about 15–20 days. However, BRRI dhan 45 is the shortest lifespan variety and market price is higher than the other demonstrated variety. So from the above discussion it could be said that for addressing the risk of flash flood BRRI dhan 45 could be adopted in this area and also BRRI dhan 29 could be also cultivated with some crop manipulation techniques.

Pulse crop (Mughbean, Lentil): Both these two varieties of pulse were found very new in this area. Though it needs relatively shorter time compare to traditional Boro Rice (Table 11.5), but it needs lot of motivation among the farmers to adopt these verities. Both high and low kanda that are fallow could be used for the cultivation of these verities. So it could add a new dimension in the production. Total cultivation time is less than 140 days for both the two crops can be harvested by March (due to cold injury, all crops took 15–20 days more compared to the normal year). So it is possible to harvest before the flash flood. For Mung bean and Lentil the life span is 129 and 102 days respectively. Usually, recession of water from raised kanda lands gets faster and the lands become ready for agriculture activity 30–45 days ahead compared to the rice fields (low lying). Again, the rice fields get inundated at the first place by the flash floods while raised kanda lands inundated at the last. Therefore these lands are quite feasible for agriculture purposes and free from risk of flash floods. Moreover, kanda lands are remaining fallow throughout the year can be used for agriculture production. Only difficulties were found in farming in the kanda lands are lack of irrigation facilities. Thus the lands are highly recommended for the crops, which need less irrigation.

Oil seed (mustard): Life span of mustard is very low in compare to other crops, which was found very suitable in the context addressing flash floods. It could grow within 100 days and as a result of that there is no threat of early flash flood in that particular crop. Cultivation of oilseed is more profitable than that of rice. Mustard was found as a potential crop, which had less insect and disease infestation, and yield was satisfactory.

Vegetables (Radish, Spinach, Garden Pea, Sweet guard, Red Amaranth, Steam Amaranth, Bitter gourd, Potato, Ash gourd, Ariod): Cultivation of vegetable is not popular in the haor areas and therefore not practiced by the farmers. Interview notes revealed that only few women members used to cultivate vegetables at the homestead and court yard level. But the team has found a huge potential of growing vegetables in the haor areas. Fallow kanda lands were found potential area for growing some kinds of vegetables. All of the above vegetable crops were found more profitable than many other crops. All the vegetable crops were tried to cultivate in homestead and adjacent area and fallow kanda land and some vegetables like potato, garden pea, bitter gourd etc. is possible to grow in the others land in the haor. All vegetable crops were possible to harvest before flash flood and proved to be profitable. Especially, sweet gourd performs better in roadside and fallow land. On the other hand, potato needs some special care when cloudy weather, heavy fogging and high humidity condition appear. January to March months were found peak poverty period in the haor areas and the vegetable can be used as cash crop can highly contribute to address peak poverty situation as well as the flash floods.

Spices (Onion, Garlic): Spices like Onion and Garlic is very new to haor area. However, spices could be taken as an alternative of rice because of spices have more productivity and more profitable than rice and some of the spices can grow in the lands suitable for rice as well. Spices usually take more time than vegetables, oil and pulse crops. But it could be harvested before the flash flood. So these crop varieties were found very much potential for the Haor areas to address flash floods. Profit percent is very high. In addition, infestation of disease and pest was very low. A small piece of land can generate huge profit margin therefore it was found very suitable for small and marginal farmers.

11.4.1 Erratic Flash Flood: Need for a Peoples Centered Early Warning System

Flash flood occurs in this area almost every year. Intensity differs from year to year and intra basin locations. Generally the depressed parts of the study areas are highly affected. It depends on time and quantity of rainfall in the hill and drain out capacity of main rivers. Pressure of hilly flow plus rain fed water in the rivers reach to such a level to overflow or wash out the embankments or banks of the rivers to enter the flow into the *Haor*. When flash flood due to sudden heavy rainfall creates pressure on the hydrological system, water easily overtops and creates breaches at several locations of the submersible embankment eventually water quickly enter into the *haor*.

Table 11.6 Key causes of flash flood in the *Haor* area

Causes of flash flood	Factors responsible
Insufficient drainage system of rivers and canals	Deforestation in the hills, unplanned construction of groan and earthen roads lead to ineffective drainage systems. Siltation/sand deposition enhances the affect of flash flood
Excessive rainfall and increased runoff from hills	Deforestation in the hills, global climate change effect, and reduced water retention capacity of hill-soil
Ineffective/weak embankment and dam	Extended hilly flow and ineffectiveness of natural drainage system put extra pressure on embankments. On the other hand weak consolidation of newly constructed embankments failed to meet the pressure
Inappropriate reconstruction of embankment	Lack of active participation of local people in planning and implementation work increases systemic corruption in implementation of repair work through UP & BWDB hampered construction work
Reconstruction of crop protection embankment are not done on time	Lack of sincerity of the relevant authority, delay in financial allocation and corruption in the construction work delays the completion of the work before flash flood event
Inadequate number of sluice gates and culverts in the embankments	No involvement of local people in planning and implementation, inadequate funds are responsible for inadequate sluice gates in the area that put pressure on embankments
Lack of maintenance and effective use of sluice gates	Absence of certain maintenance facilities from government or local level institutions and lack of trained manpower for effective use of sluice gate extends the affect of flash flood
Deforestation in the hills and floodplains	Extensive cutting of trees for boat construction, establishment of *katha* in the beels, furniture making, firewood and conversion of land for agriculture and limited new plantation make adverse affect
Rats, crabs, fishes makes hole in the embankments causing easy collapse	Due to destruction of natural habitat for the boring animals they take shelter on embankment causing damage and water leakage resulting in decreasing effectiveness of the embankment. There is also lack of adequate plantation along the embankments to reduce the soil erosion
Decreased width and depth of rivers/canals/stream	Illegal encroachment practice by the local influential as well as due to extension of agriculture practices

Most of the cases, flood water comes into the *haor* very early in the monsoon and farmers do not get sufficient lead time to harvest their standing *boro* crop.

The objective of people-centered early warning systems is to empower individuals and communities threatened by the hazards, especially flash flooding, to act in sufficient time and in an appropriate manner to reduce the possibility of crop loss, loss to livelihoods, and damage to property and the environment. Early warning is a major element of disaster risk reduction. To be effective, early warning systems need to actively involve the communities at risk, facilitate public education and awareness development on risks, effectively disseminate messages and warnings and ensure there is constant state of preparedness (Table 11.6).

As has already been mentioned, the *haor* areas are flooded during cropping season every year in the last 10 years, except years 2005 and 2008. Flash floods in most areas, strike at the beginning of April (mid *Chaitra*), although in some areas of the district, flash flood hit as early as the beginning of *Chaitra*—particularly in areas of Tahirpur and Sulla. Further, on rare occasions floods have been known to occur in February (*Falgoon*). Interestingly, villagers in the majority of the areas suggested that increases in siltation (mainly riverbeds) in the recent past has worsened the effects of flash flooding, sometimes citing flood control structures (sluice gates, embankments, dikes, etc.) as the primary causes. It is also possible that deforestation and quarries in the Meghalayan hills are contributing to increase siltation in the district.

Common rice cultivation generally is *Boro* (*Jugli* and *shail*) and BRRI varieties (BR11, BR18, BR26, BR28, BR29). From seedling to harvest the average period until maturation is 3–3.5 months for *Boro* and 4–5 months for BRRI varieties (except BR28). Harvesting usually starts at the end of *Chaitra* and continues for the entire *Baishakh*. In isolated pockets other *boro* varieties such as *LalJingi*, *Tepi*, *Rata*, but in negligible quantities (where grown, at most 10 % of the total crop). In most of the areas visited there is no history of commercial *Rabi* crop cultivation. Cultivation that does take place there is usually small-scale cultivation for personal consumption. When asked about short duration paddy, villagers generally mentioned BR28, and on one occasion *Aus*, but no other.

There is a surprising wealth of indigenous knowledge by which villagers can predict that flash flooding will occur. The most obvious, identified in all areas visited was the appearance of dark clouds in the sky and stormy weather. Another commonly mentioned sign is the appearance of storm clouds and rains on the Meghalayan foothills, or, the foothills becoming distinct on the horizon. River swelling was also commonly cited as an indicator of impending flooding, whilst less frequently, but in all Upazilas southern wind was also mentioned.

In the past, villagers in most areas would build makeshift embankments to contain flood water, as and when flash flood occur, or hastily repair damaged (existing) embankments at the eleventh hour. Crucially, no preplanned action is usually taken in advance (e.g. at the start of the dry season) to prevent crop damage in the area. The aim of these repairs was to protect the land for very short time (at most 1 week) so that the respective villagers could harvest their paddy. In order to make temporary embankments villagers generally works together, using soil and bamboo *pala-siding* to contain water. In most areas, however, if the paddy is ready to harvest, villagers harvest as much rice as possible before flood water inundates the *haor*.

Flash flood occurs in the area almost every year. Intensity differs from year to year and in various basin locations. Generally, the deeper parts of the areas are highly affected. Severity depends on time and quantity of rainfall in the hill and drain out capacity of main rivers. Pressure of hilly flow plus rain fed water in the rivers reach to such a level to overflow or wash out the embankments/dams or banks of the river/canal and to enter into the *haor*. This situation is locally called *apor-mara*. Basically *apor* means the embankments or raised banks of river/canal. Early invasion of flash flood causes heavy damage to the standing crops of the *haor*

Table 11.7 Extent of flash flooding in Sunamganj District

Year	Flood water entered the *haor*	Inundating the *boro* crops	Extent of damage	Damaged *boro* crop in hector	Cost of damaged crops in Lac
1996	16 March	18 March	75 %	29,822	4,102.07
1997	22 May	24 May	15 %	9,830	1,278.84
1998	20 May	23 May	40 %	11,579	2,365.02
1999	03 May	06 May	45 %	10,950	976.65
2000	28 April	30 April	70 %	1,355	420.14
2001	27 April	30 April	75 %	4,963	1,899.95
2002	14 April	18 April	70 %	21,677	7,058.16
2003	27 May	30 May	20 %	20,997	8,666.87
2004	13 April	15 April	90 %	95,402	34,860.40
2005	22 May	25 May	15 %	–	–

Source: Community response and DAE Sunamganj

leaving no or limited scope for harvesting. Flash flood not only damages crops but also the cause water logging within the *haor* due to low runoff capacity of rivers and canals.

Though the most devastating flash flood occurs generally during the end of *Chaitra* to *Baishakh,* people informed that two to four times there is sudden increase of water level till *Agrahayon*. In recent times, flash flood causes more damages than the past. In recent past, the most severe one occurred in 2004. People reported that this was the first time that they experienced such type of flash flood damages (Table 11.7).

The CDMP study on Early Flash Flood Modeling in the Haor region has estimated around 40 h catchment lag time using the hydro-climatic information (Sumon 2009). This may further be advanced using the cloud modeling and distant rainfall forecasting at the upper catchment in India. Also using the DEM database will improve the assessment of real time damage and loss forecast. Local farmers were asked to respond on what should be the minimum lag time to secure the standing crops and properties. For agriculture and protection of homesteads and outside property, the lead time needs to be at least 7 days to save at least 70 % of the asset, while 2-days lead time is sufficient to save household items, livestock and poultry (Table 11.8).

The community members and the UDMCs[8] were interviewed to identify the necessary requirements for an effective EWS and the potential interventions for a successful response and recovery. Especially, the crop protection strategies got the highest importance to the community members during discussion.

- Extend regular support of Bangladesh Water Development Board (BWDB) in the Upazila to discuss the problems;
- Dredging rivers and canals to facilitate drainage of flash water;

[8]Union Disaster Management Committee (UDMC) headed by the Chairman of the Union Parishad to co-ordinate, review and implement the disaster management activities of the concerned union.

Table 11.8 Lead time preference to save different assets

	Days[a]		
Items	One day	Two days	Seven days
Structures			✓
House contents		✓	
Outside property			✓
Livestock		✓	
Agriculture			✓
Culture fisheries			✓

[a]Indicates lead-time required to save 70 % or more of the asset

- Embankments and canals maintenance should be done on time;
- Plantation along the embankments to reduce soil erosion;
- Flood protection plan and implementation scheme should be carried out with the active participation of people;
- People's participation is also to be ensured for management and maintenance;
- Ensure people's access to Government rehabilitation services;

For easy protection against the flood impact, the small and marginal farmers should be given training on Alternative Income Generating (AIG) activities and provided with basic capital:

- The plan should be prepared and implemented to facilitate draining out of rainwater and floodwater;
- The embankments should be reconstructed to protect the flash flood;
- The areas can be compartmentalized for flood protection development activities;
- Damaged embankment should be reconstructed through the local committee to complete the necessary work on time;
- Establish and construct 10–12 submersible culverts around the *haor* as more water can be drained out;
- Construct a regulator across the linking canal between the Angurali and Sonar *haor* as water can be regulated to protect the crop;
- Government should initiate flood preparedness program involving community.

11.5 Haor and Wetland Development Master Plan

Bangladesh Government has created Bangladesh Haor and Wetland Development Board under the Ministry of Water Resources to address the development issues of the haor region. Recently this Board has drafted Master Plan of Haor areas in April 2012. The development of the Haor Master Plan 2030 offers the possibility of developing a long term vision of the transformational change in the haor region with a future direction on governance, planning and budgeting of comprehensive development including management of natural resources and utilizes limited public and private resources more effectively through multiple objective oriented interventions.

The strategy of the Master Plan focuses on achieving the objectives of sustainable development based on certain key principles. The strategy is formulated for optimal use of available natural resources with least interruption to the haor ecosystem. In order to address the needs and issues, this Master Plan has followed six thematic strategic areas for integrated development such as (a) improved water and disaster management; (b) agricultural development for food security; (c) biodiversity enhancement and wetland management; (d) social safety net and improved standard of living; (e) improved physical infrastructure and (f) enterprise and technology development.

This Master Plan has identified 8 water resources projects, 20 agricultural development projects, 22 fisheries development projects among others. Implementation of the proposed agricultural and water resources management investment portfolio projects in the Master Plan are expected to bring about positive changes. At present, the cropping intensity of haor districts is 147 % and with project investment scenario, it is expected to be 185 %. Incremental food grain production in post project condition is estimated to be increased by about 2.07 million metric ton/year. The Master Plan also anticipated that there will be significant increased (200 %) of non-rice crop areas.

11.6 Concluding Remarks

The policy instruments package should be aimed at sustainable wise use of natural resource while ensuring equity and justice in benefit sharing while managing the resources in a participatory approach. In this context, wetland protected area concept such as sanctuary declaration of the dry season water body may also become an effective tool in sustaining our aquatic resources including fisheries by protecting key habitat and nursery areas. Given that wetlands are often open access resources, it is imperative that communities be charged with the responsibility of managing them to reduce over utilization. The envisaged policy implication is to take into account household welfare besides institutional innovations and hybridizations as part of the policy package towards sustainable use of wetlands. Access to wetland resources with legal support is a critical factor in strengthening poor haor people's livelihoods. Creating opportunities for expansion and enhancement of common property resources for the target poor population in critical eco-specific sites as well as tackling inequitable and insecure access to natural resources that will encourage sustainable management, is the most important action needed to reduce poverty and improve environment and natural resource condition. Activating local government and other local organizations to provide and attach to more responsive services to the local communities through multi-sectoral interventions needs attention while planning local haor development intervention.

Agriculture being the mainstay of livelihood needs special attention which has been reflected in the Haor and Wetland Master Plan. However, priority should be given on application and transfer of climate resilient modern cropping pattern technology to the farmers so that double and triple crops can be harvested by utilizing fallow land. Also adoption of technology for minimizing labour and time cost for harvesting and planting/sowing of crops to protect the crops from flash flood damage. Cultivation of innovative agriculture through floating bed is another opportunity for livelihood support in lean monsoon season.

References

Bangladesh Haor and Wetland Development Board (2012) Master Plan of Haor Areas, vol II. Main report. Ministry of Water Resources, Government of Bangladesh, Dhaka

CEGIS (2012) Master plan of Haor area – summary report, vol 1. Ministry of Water Resources, Government of Bangladesh, Dhaka

Climate Change Cell (2008) Climate Change Adaptation Research – adaptive crop agriculture including innovative farming practices in Haor basin. Department of Environment, Dhaka

CNRS (2007) GIS based mouza maps of two upazilas in Sunamganj 2006–07. CNRS Community Based Resource Management Project – Local Government Engineering Department

CNRS-ActionAid Bangladesh (2008) Establish rights of poor and marginalized people, asset development, improve access to social services, especially basic education, unpublished project report

Sumon A (2009) Flash flood and adaptive crop agriculture in north-eastern bangladesh: peoples centered early warning system for erratic flash floods in the haor region, VDM Verlag, Germany

Chapter 12
Agriculture Adaptation in Coastal Zone of Bangladesh

Md. Anwarul Abedin and Rajib Shaw

Abstract Nowadays, climate change is one of the greatest threats to human lives and livelihoods in coastal regions all over the world and especially, coastal zone of Bangladesh is facing tremendous challenge from climate change. Furthermore, Climate change and agriculture possess an inverse relationship where climate impacts hamper agri-production. Among other sectors, agriculture is facing deadliest experiences from climate change related natural disasters, as agriculture is the main livelihood option for the coastal people of Bangladesh. Hence, agricultural adaptation approach is one of the key aspects that are helpful to reduce agricultural crop vulnerability in the coastal zone of Bangladesh. In this connection, considering local level experiences, the main objective of this chapter is to find out suitable and viable adaptation measures that have the potential to help farmers to adapt climate change. These adaptation practices include identification of suitable cropping pattern, choice of seed, irrigation water management, crop intensification suitable transplanting and so on. Therefore, the first part of this chapter illustrates the changing pattern of climatic parameters mainly temperature and rainfall in the whole country alone with coastal zone sea level rise and cyclone; and the impacts of climatic variability on crop production in the southwestern areas. Then the focus shifts on brief profile of the coastal zone including geographical location and geophysical environment. The last part of this chapter provides recommendation on possible adaptation techniques that have the potential to help farmers to adapt climate change and reduce yield loss in achieving food security.

Keywords Agriculture • Agriculture adaptation practices • Climate change • Coastal zone of Bangladesh • Impacts

Md.A. Abedin (✉) • R. Shaw
Graduate School of Global Environmental Studies, Kyoto University, Kyoto, Japan
e-mail: masumagriculture@yahoo.com

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*, Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_12,

12.1 Introduction

Bangladesh is one of the most vulnerable countries to climate change because of geographic exposure, low income and greater reliance on climate sensitive sectors, particularly agriculture. However, agriculture is the most important livelihood option for the coastal people of Bangladesh (GoB and UNDP 2009). It has a key role to play in tackling the challenges of the growing population, poverty alleviation, maintaining food security and adapting to climate change (BCCAAP 2010; BPRSP 2005). It has been identified as being of prime importance for achieving development goals in coastal areas (BPRSP 2005). About 40 million people of the coastal areas of Bangladesh depend on agriculture (BBS 2011).

From the 1980s to the present, shrimp cultivation has created a substantial economic and social transformation in those coastal areas where it has been taken up (DoF 2010; Hamid and Alauddin 1998). Furthermore, in recent years, shrimp has become a significant foreign exchange earner for Bangladesh (DoF 2010; Mahmood 2006). However, shrimp farming is a subject of criticism since it can damage the local ecology by increasing the salinity of the water and soil, change the composition of the soil and bring about rapid changes in land use and land cover (Deb 1998; Hagler 1997; Haque 2004; Islam 1999; Karim and Stellwagen 1998). There are also claims that it has led to disintegration of economic and social conditions of coastal rural communities (Ali 2004, 2006; Islam and Koudstaal 2003; Mahmood 2006).

Because of environmental and social impacts associated with shrimp cultivation, farmers of some parts of the coastal areas are incorporating vegetables and domestic animals into existing farming practices, integrating shrimp or prawn and fish with rice and vegetables. As a whole the people of the coastal areas are trying different agricultural practices to cope with the changing environment (Mahmood 2006). This transformation of agriculture has many positive effects and has reduced some risks in farming. However, there is a growing concern on how this transforming agriculture is coping with the existing physical and social economic environment, how it is supporting people of the area and how beneficial it is in comparison with shrimp cultivation or traditional agricultural practices.

Climate change and agriculture possess an inverse relationship where climate impacts hamper agri-production. However, unsustainable agriculture contributes to greenhouse gas emissions. Rainfall and temperature are two climatic variables that shape the structure of socio-ecological system. Any alternation of rainfall and temperature cycle, as a result of climate change, eventually hampers agriculture production. Changes in soil moisture and temperature, evapo-transpiration, rainfall and possible increases in heat stress will affect the growth of some subsistence root crops and vegetables. Being a climate sensitive sector, agriculture in Bangladesh is totally dependent on seasonal weather variability.

Considering experiences on local level, the main purpose of this chapter is to find out suitable adaptation measures that have the potential to help farmers to adapt climate change. These include identification of suitable cropping pattern, choice of seed, irrigation water management, crop intensification and suitable transplanting. The first section of this chapter illustrates the changing pattern of climatic parameters mainly temperature (monthly and yearly average maximum and minimum temperature) and rainfall in the whole country alone with coastal zone sea level rise and cyclone; and the impacts of climatic variability (changing temperature and rainfall pattern) on crop production in the southwestern areas. The second portion focuses on brief profile of the coastal area including geographical location and geophysical environment. The last section of this chapter provides prescription on possible adaptation techniques that have the potential to help farmers to adapt climate change and reduce yield loss in achieving food security and finally conclusions and recommendation.

12.2 Climate Change Scenarios and Impacts on Crop Agriculture

This part depicts the climate change scenarios considering temperature, precipitation, sea level rise and coastal cyclone and its impact on crop agriculture, which enhances food security vulnerability and millions of hunger mouth in the coastal zone.

12.2.1 Climate Change Scenarios

Climate change scenarios are briefly illustrates in the following sub heading.

12.2.1.1 Scenario for Temperature and Precipitation

Temperature as well as precipitation plays vital role in the process of climate change. In early 1990s General Circulation Models (GCM) were extensively used for generating climate change scenarios for Bangladesh. The BUP-CEARS-CRU (1994) study reported a 0.5–2.0 °C rise in temperature by the year 2030. The same modeling effort estimated a 10–15 % rise in average monsoon rainfall by the year 2030. Using four GCMs (CSIRO9, CCC, GFDLH, and UKMOH), ADB (1994) conducted a study and reported that, the temperature would rise by 0.3 °C for 2010 with a corresponding rise of 1.5 °C for 2070.

All these four models provided different results for developing monsoon rainfall scenarios. The high-estimating GFDL model (GFDLH) projected 59 % higher rainfall for South Asian monsoon with a corresponding withdrawal of dry season rainfall by 16 %. The CCC model, however, projected an increase of monsoon rainfall by 20 % and withdrawal of dry season rainfall by 6 %. Both considered a doubling of CO_2 concentration in the atmosphere (therefore, time independent). A time-dependent modelling provided a medium scenario for South Asian rainfall: the monsoon rainfall was projected to increase up to 5 % by 2010 and between 5 % and 30 % by the year 2070, while the dry season rainfall was projected to vary between

−10 % and +10 % by the year 2070. For the time dependent medium-scenarios, it was assumed that the concentration of CO_2 would be 400 and 640 ppmv by the years 2010 and 2070, respectively (ADB 1994).

Model-driven climate change scenarios were generated under the "Climate Change Country Studies Programme" using the Canadian Climate Centre Model (CCCM), the Geophysical Fluid Dynamics Laboratory equilibrium model (GFDL), and the 1 % transient model of GFDL (i.e., GF01) (Ahmed et al. 1998; Asaduzzaman et al. 1997; Huq et al. 1998). The outputs of the three GCMs for the 1990 base year were validated against a long-term "climate normal", as provided in the published report. Applying the same methodology, Ahmed et al. (1998) reproduced climate change scenarios, which were largely used for a number of subsequent national assessments. Table 12.1 summarizes the results of such scenario development exercises.

Instead of developing one or more scenarios the National Adaptation Programme for Action (NAPA) for Bangladesh has developed a climate change scenario for the country. The NAPA Core Team (GOB 2005) adopted the results obtained by Agrawala et al. (2003) for changes in temperature. Regarding changes in precipitation it modified the results of Agrawala et al. (2003) based on the judgment of the NAPA Core Team and not on the reflection of any GCM modelling exercise. The scenario provided by the NAPA document is given in Table 12.2 for comparison. The NAPA document has also provided a sea-level rise scenario for Bangladesh. Apparently, the upper values of the IPCC SLR scenarios (WGI, TAR: IPCC 2001) were adopted for developing the scenarios for 2050 and 2100, while the curve was extrapolated for developing the 2030 SLR scenario.

12.2.1.2 Scenario for Sea Level Rise

For sea level rise, the scenarios have so far been largely speculative, not based on any modelling. For sea level rise, a range of 30–150 cm was assumed by Mahtab (1989) for the year 2050. However, a median value was considered by taking the mean of the two limits and adding 10 cm for local subsidence, which provided for a 100 cm "net sea level rise" by the year 2050.

In the absence of a Bangladesh-specific sea level rise scenario, the IPCC scenarios for sea level change were taken as a basis for developing net sea level change along the coastal zone of Bangladesh, Halcrow et al. (2001) as cited in CCC (2009). Considered a linear rise in sea level by 1 mm/year, which resulted in a 30 and 50 cm rise in sea level by the year 2030 and 2050, respectively. The NAPA document has provided a sea-level rise scenario for Bangladesh. However, no explanation has been provided in support of the data. Apparently, the upper values of the IPCC SLR Scenario (WGI, TAR: IPCC 2001) was adopted for developing the scenarios for 2050 and 2100, while the curve was extrapolated for developing the 2030 SLR scenario.

The low-lying topography of the coastal landforms in Bangladesh suggests that a change in sea-level can have catastrophic impacts and increase vulnerability significantly.

Table 12.1 Outputs of GCM exercise using GFD 01 transient model

Year	Average temperature			Temperature increase			Average precipitation			Precipitation increase		
	W (°C)	M (°C)	Ave (°C)	W (°C)	M (°C)	Ave (°C)	W (Mm/month)	M (Mm/month)	Ave (Mm/month)	W (Mm/month)	M (Mm/month)	Ave (Mm/month)
1990	19.9	28.7	25.7	0.0	0.0	0.0	12	418	179	0	0	0
2030	21.4	29.4	27.0	1.3	0.7	1.3	18	465	189	+6	47	10
2075	22.0	30.4	28.3	2.1	1.7	2.6	00	530	207	−12	112	28

Source: Ahmed et al. (1998)
Note: *W* stands for winter (i.e., December, January and February: DJF) and *M* stands for monsoon (i.e., June, July and August: JJA)

Table 12.2 Scenarios provided in NAPA document

Year	Temperature change (°C) mean			Rainfall change (%) mean			Sea level rise (cm)
	Annual	DJF	JJA	Annual	DJF	JJA	
2030	1.0	1.1	0.8	5	−2	6	14
2050	1.4	1.6	1.1	6	−5	8	32
2100	2.4	2.7	1.9	10	−10	12	88

Note: Despite the claim, the values in the shaded cells are not directly adopted from Agrawala et al. (2003). No explanation has been provided in relation to the deviations from the model-resolved ensemble data. Standard deviations were not shown. *Source*: Adopted from the Bangladesh NAPA Document, GOB (2005)

The GBM delta is morphologically highly dynamic and the coastal lands are simultaneously subject to accretion and tectonic subsidence (Huq et al. 1996; Allison et al. 2003 cited in CCC 2009). Compaction of sediment may also play a role in defining net change in sea level along the coastal zone due to the fact that the landform is constituted by sediment decomposition. Lacking more specific information, if one assumes that sediment loading cancels out the effects of compaction and subsidence, the net sea-level rise can be assumed to be close to the global average as projected by the IPCC.

The latest IPCC scenario (IPCC 2001) provides a globally averaged sea level change scenario that projects a rise of 9–88 cm by the year 2100. Considering a non-linear rate of change owing to the gradual accumulation of greenhouse gases in the atmosphere, the range of sea level rise will be 2–20 cm in 2025 and 4–39 cm in 2050. The "net sea level rise" will be 4.5–23 cm in 2025 and 6.5–44 cm in 2050. Since the projected adverse impacts will be much higher for the latter case, the lower values for sea level rise may be ignored.

12.2.1.3 Scenario for Cyclone Along the Coastal Zone of Bangladesh

Very little is found in the literature on future plausible changes in cyclone intensity along the coastal zones of Bangladesh. The BCAS-RA-Approtech (1994) study considered a net increase in 10 % intensity in cyclone activities, which was based on expert judgment. Ali (1999) as cited in CCC (2009) commented that an increase in 2 °C is SST would likely cause a significant increase in the probability of formation of cyclones from a mere depression. The IPCC Third Assessment noted that currently available models could not do a good job towards resolving the influence of climate change on cyclones (IPCC 2001). However, based on emerging insights from a few climate model experiments as well as the empirical records, the TAR of IPCC concluded that "… there is some evidence that regional frequencies of tropical cyclones may change but none that their locations will change. There is also evidence that the peak intensity may increase by 5% and 10% and precipitation rates may increase by 20% to 30%" (IPCC 2001).

12.2.2 Impacts on Crop Agriculture

Agriculture is one of the most vulnerable systems to be affected by climate change in the south Asian region. The climate in Bangladesh is changing. It is becoming more unpredictable every year and its variability is being experienced more frequently than ever before. Hazards like floods, droughts, cyclones and others are likely to be aggravated by climate change. Salinity intrusion would be a more acute problem in the coastal region. This will have extra bearing on the agriculture and the potable water in that region. The salinity conditions in the coastal area of Bangladesh could further exacerbate due to reduced dry-season freshwater supply from upstream sources resulting from climate change (IPCC 1998) and saline water intrusion due to sea level rise.

It is believed that climate change would increase the disparities in cereal production between developed and developing countries. Farm-level adaptation would be inadequate in reducing the disparities. It is also reported that even an extensive farm-level adaptation in the agricultural sector would not entirely prevent such negative effects. In general, the tropical and subtropical countries would be more vulnerable to the potential impacts of global warming through effects on crops, soils, insects, weeds and diseases. Impacts of climate change would cause enhanced vulnerability to the crop production systems in Bangladesh.

As there is a strong possibility that winter precipitation will decrease, it is likely that moisture content of topsoil would decrease substantially. Due to temperature rise, the high rate of evapotranspiration will result in an acute drought condition in winter months. Consequently, a late Kharif II drought in December would adversely affect Aman crop at the ripening stage, while an early rabi drought would more severely affect wheat and boro crops at both germination and vegetative growth stages (Karim et al. 1998). Furthermore, increasing moisture stress in early Kharif I would significantly affect Aus production.

Together with the possible reduction in Aman rice area (as a result of greater spread of flood waters, and longer duration of flooding) and a reduction in boro rice area (which will be limited by available surface and ground water for irrigation), the total area suitable for rice production may in the future stagnate or possibly decrease (WB 2000). CEGIS (2006) has shown that due to sea level rise along the southwestern region of Bangladesh Aman suitable areas would decrease significantly.

In the winter months the coastal croplands suffer due to salinity related problems. In the absence of appreciable rainfall the soil in the coastal areas starts to desiccate, and because of capillary actions salt comes up at the surface of the soil and accumulates at the root zones. Salinity problem is often intensified when high spring tides inundate low-lying coastal areas, especially when they are associated with cyclonic storm surges. Many of the crop varieties, especially those of food grain varieties, are not salinity tolerant. As a result, a large area in the coastal districts is virtually unsuitable for a number of crops, while the production of a few other crops is lesser under saline conditions. Since salinity intrusion restricts cultivation of boro and wheat, the potential impact cannot be ascertained. However, the varieties that are grown with the given conditions, about 0.13 Mt of food grain is lost annually due to adverse impact of soil salinity. It is reported that the effect of soil salinity on Aus production would be detrimental, and Aman season rice crop, when grown under severe climate change scenarios, could also suffer over twofold yield reductions (Habibullah et al. 1998).

Flood affects agricultural production considerably. The 1988 flood caused reduction of agricultural production by 45 % (Karim et al. 1998). Higher discharge and low drainage capacity, in combination with increased backwater effects, would increase the frequency of such devastating floods under climate change scenarios. Prolonged floods would tend to delay Aman plantation, resulting in significant loss of potential Aman production, as observed during the floods of 1998. Considering all the direct and induced adverse effects of climate change on agriculture, one may conclude that crop agriculture would be even more vulnerable in Bangladesh in a warmer world (WB 2000).

12.3 Brief Profile of the Coastal Areas

This section focuses on location, extent, topography, and administrative unit of the coastal area as well as geophysical environment too.

12.3.1 Overall Geography, and Location

The coastal zone of Bangladesh covers 47,201 (32 %) km^2 land area of the total geographical area of the country (Shamsuddoha and Chowdhury 2007; MoWR 2005). The entire zone is low lying with 62 % of land have an elevation of less than 3 m and 86 % less than 5 m (Islam et al. 2006). Depending on elevation and other factors, the defined coastal area can reach from 37 to 195 km from the shore (MoWR 2005). The whole coast runs along the northern border of the Bay of Bengal, forming a 710 km long coastline (MoWR 2005).

Physiographically most of the coastal zone consists of extensive flat coastal and deltaic land of the Ganges–Brahmaputra Delta, which is crossed by large tidal rivers discharging into the Bay of Bengal (Rashid and Kabir 1998). In general, much of the western part of the coastal zone is a moribund or mature delta; the middle part is an active delta; and the eastern part is a stable landmass (Ahmad 2003). Continuous accretion and deposition are taking place in active delta of the coastal regions due to strong river and tidal currents (Chowdhury and Hossain 2006).

The coastal region covers 19 administrative districts encompassing 153 upazilas (sub-districts, formerly called thanas) and the Exclusive Economic Zone (MoWR 2005). Out of these 19 districts, 12 meet the sea or lower estuary directly (MoWR 2005). Among the upazilas, 51 from 12 districts face the coast or lower estuary and these areas are known as exposed coast (Islam et al. 2006; PDO-ICZMP 2003). The remaining 102 upazilas that are further inland from the exposed coast are within what is termed the interior coast (MoWR 2005). The upazilas in the exposed coast have already met or crossed the threshold limit tidal movement, salinity, cyclone risk—and the upazilas in interior coast have met or exceed any two or one of the three parameters (PDO-ICZMP 2003). In the coastal zone, 62 % of land has an elevation of 3 m or less and 86 % is less than 5 m above sea level (Islam et al. 2006). Since the 1960s, the southeast coast of Bangladesh is protected by implementing cross dams (William and Gravgaard 2010). The coastal people pursue their livelihoods in a unique environment with a combination of natural disasters and man-made changes (WRPO 2006).

The National Strategy for Accelerated Poverty Reduction (BPRSP 2005) acknowledges the Coastal Zone as a special focus area that is distinct in many respects and requiring of special attention acknowledging the fact that "there is considerable interface between the persistence of chronic poverty and unfavorable agricultural environments, (e.g. salinity-prone, flood-prone, river- erosion prone, drought-prone areas)". Later on, the Government of Bangladesh formulated Coastal Zone Policy, 2005 and Coastal Development Strategy, 2006 and adopted an Estuary Development Programme along with other initiatives to address coastal vulnerabilities.

According to 2011 Population Census, the coastal zone comprises 6.85 million households with a population of 35.1 million (BBS 2011). In the coastal zone the net cultivable area is 1.95 million ha indicating that the average landholding per household is half the already small national average. The net-cropped area of coastal zone in Bangladesh has been decreasing over the years due to various causes that are soil-related or associated with climate risk and socio-economic problems; the most common one is land inundation and salinity intrusion by tidal water. A comparative study of Bangladesh Soil Resource Development Institute (SRDI) shows that from 1973 to 2000 about 0.170 million ha (20.4 %) land of coastal areas is affected by salinity (SRDI 1997, 2001).

One of the main economic activities in the coastal zone is aquaculture (Islam and Ahmad 2004). The significance of shrimp farming has grown rapidly over the last 30 years (Alam and Phillips 2004). Shrimp areas have expanded from 51,812 ha in 1983 to 137,996 ha in 1994 and 218,649 ha in 2004 (DoF 1995, 2005). At present, Bangladesh supplies around 2.5 % of the global shrimp trade (DoF 2004).

12.3.2 Geo-Physical Environment

12.3.2.1 Drainage and Flooding

CEGIS has carried out a study to gather information on the geo-physical environment of the coastal area especially Satkhira District in 2006. The total area of Satkhira district is about 3,300 and about 1,800 km^2 is under protected area.

Table 12.3 Flood situation in Satkhira district in 2000

Total area (km^2)	Area flooded (km^2)					
3,317.1	Dry	0–30 cm	30–90 cm	90–180 cm	180–300 cm	>300 cm
	1,058.4	534.2	1,008.8	515.2	200.2	0.6
	% of area flooded by depth in cm					
	Dry	0–30 cm	30–90 cm	90–180 cm	180–300 cm	>300 cm
	31.9 %	16.1 %	30.4 %	15.5 %	6.0 %	0.0 %

Source: Climate Change Cell (2009)

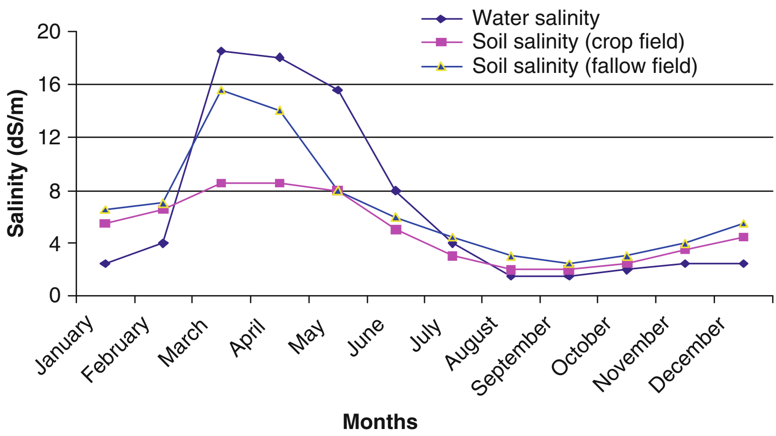


Fig. 12.1 The soil and water salinity dynamics at Benarpota Farm, Satkhira, during 2001–2004. *Source*: Climate Change Cell (2009)

Hundreds of sluices/regulators have been constructed on the embankments primarily for draining rainwater, and secondarily to prevent seawater from entering into the polder. The flooding and drainage situation for base condition was estimated based on the flood of year 2000. The flooding area of Satkhira district has been categorized in depth classes as: dry, 0–30 cm, 30–90 cm, 90–180 cm, 180–300 cm and >300 cm in keeping similarities with the widely practiced land classes: F0 (dry to 30 cm), F1, F2, F3 and F4. The flood status in base condition within the study area is shown in Table 12.3.

12.3.2.2 Salinity

The soil and water salinity dynamics are shown in Fig. 12.1 Long-term data on Satkhira revealed that soil salinity in the crop fields ranged from 4.5 to 8.5 dS/m and fallow lands with that are relatively more saline ranged from 5.5 to 15.5 dS/m CCC (2009).

Table 12.4 Salinity tolerance levels of rice crops

			Salinity (in dS/m)	
SL no.	Variety	Season	Seedling stage	Maturity
1	BRRI dhan47	Boro	12–14	8
2	BRRI dhan40	T. Aman	8	8
3	BRRI dhan41	T. Aman	8	8
4	Other varieties	Have no reported salt tolerance level		

Source: Climate Change Cell (2009)

12.3.2.3 Current Crops Practice

The major cropping pattern in Satkhira Upazila is Fallow–T. Aman–Fallow and Fallow–T. Aman–Boro. During the Kharif-1 season farmers cultivate jute, aus rice, oil seeds and different types of vegetables. During the Kharif-2 season T. Aman is the dominant crop. Different types of T. Aman rice such as BR10, BR11, BR30 and local varieties are practiced during this season. In the rabi season, boro rice such as IRRI28, IRRI44, IRRI26, and IRRI29 are practiced. Other crops that are practiced are mustard, wheat, pulses and different types of vegetables.

12.3.2.4 Salt Tolerance Levels of Selected Crops

Table 12.4 shows the salt tolerant levels for BRRI dhan47, BRRI dhan40 and BRRI dhan41 at seedling stage and maturity stage. The salt tolerant levels of other rice varieties and non rice varieties experimented in this study are not reported.

12.4 Agriculture Adaptation Practices

After describing geographical information as well as geophysical environment, this section offers some theoretical and practice oriented adaptation approaches that are helpful to reduce agricultural crop vulnerability in the coastal zone of Bangladesh as well as the whole country.

Climate variability makes crop agriculture in Bangladesh highly vulnerable. It is inferred in the available literature that crop production would be extremely vulnerable under climate change scenarios, and as a result, food security of the country will be at risk (Mahtab 1989; BCAS-RA-Approtech 1994; ADB 1994; Warrick and Ahmad 1996; Huq et al. 1996; Karim et al. 1998). Although the agricultural vulnerability will be very high and adaptation needs are paramount, very little efforts have so far been made to understand the potential of agricultural adaptation in Bangladesh. Ahmed (2000) made an early attempt to analyse the adaptation potential of the country's crop agriculture in a warmer world.

1. Typical adaptation
   Bear Crop Losses: When potential loss of a standing crop is totally accepted by the growers, bearing crop losses is an adaptation option. It is however criticized that the option is rather theoretical, with limited applicability in Bangladesh (Ahmed 2000).

   Share Losses: The anticipated crop losses may be shared among stakeholders. Provision of government subsidies and remission of taxes for the farmers operating in susceptible croplands could be other possible options where some of the losses might be shared among different stakeholders. Compensating farmers for trying out agricultural activities under high threats of crop loss can be a potential mechanism for sharing loss. Provision of insurance against crop loss has worked well in advanced economies.

   Prevent Adverse Effects: Some measures might consider preventing the losses in agricultural production. Preventive measures are anticipatory and might require large-scale investments. The building of large embankments to protect prime agricultural lands from excessive flooding may be cited as an example of preventive measure.
2. Strategic adaptation
   Climate change offers an additional challenge for policy makers and planners in Bangladesh. Business as usual is no longer good enough and new concepts are required in the management of natural resources and the socio-economic systems.

   Key adaptations in agriculture would aim at changing agriculture practices to improving water efficiency and crop diversification. This is not only in areas that affected that are affected by climate change through salinity intrusion but also in the whole country. The development and introduction of new varieties and corresponding dissemination measures are important and need to be facilitated by international research. Given the fact that, experience with the new crops and agricultural practices has to be built up and shared on the farm level, and requires investment agricultural sector may not be as flexible to climate change as is widely believed.
3. Change in crop production strategy
   Based on the nature of soil, location and climate, crop varieties and cultivation methods are to be selected. Presently, there is no such crop that can withstand salinity in the range of 6–12 dS/m in the country. But improved managements can help overcome this drawback to some extent. Bangladesh Agricultural Research Institute has found that using raised beds, mulches and drip irrigation, it is possible to grow high value horticultural crops like, tomato, chilli, watermelon and cucumber in saline soils of 4.5–11.0 dS/m (Islam et al. 2006). Development of new technology such as crop varieties tolerant to heat and medium to high soil salinity is time demanding. Research is underway to find crop varieties of such characteristics. Until new varieties come up, adequate emphasis is to be given on the crop production management systems. From now on, demonstrations to be done in farmers field with what appropriate technologies are available so that the farmers get acquainted with these technologies and learn to adopt new technologies. Likewise, more emphasis to be given to variety development and to environment friendly pest and disease controls.

4. Introduction of Boro rice and shrimp (Lobster) cultivation
   In slightly saline and moderately saline areas, cultivation of Boro rice and sweet water shrimp will help reclaim sail salinity. In Khulna-Bagerhat region it is called "Lockpur model". IT is one kind of fish cultivation where both crops and fishes are cultivated alternatively at the same time. A dyke/ail/bund is to be built along the boundary of the plot by digging ditch inside the dyke. The length, breadth and height of the dyke will depend upon the flooding depth in the monsoon season. The ditch will be used as water reservoir for fish culture and small scale irrigation. For Boro rice cultivation good quality of groundwater may be used. By adopting this type of land use soluble salts can be leached out easily in a short time.
5. Change land use:
   In case it becomes extremely risky to continue agricultural activities under an altered climate scenario, an alternative land use might be considered as the next available option. If the suitability of Aus paddy in pre-Kharif months (March–June) appears to be too low, farmers should alter the land use and instead grow other suitable crops. Such alterations should ideally lead to acceptable economic returns, optimizing social goods and services. The application of an indigenous practice through capacity building and extension has allowed farmers of Jessore District to profitably change their land use and maintain livelihoods (Ahmed and Schaerer 2004).
6. Floating gardens (Baira)
   In seasonally flooded areas, local people from the south-west of Bangladesh have developed ingenious floating rafts with a bamboo base, upon which water hyacinth is piled and then covered by other aquatic plants or coconut husk to form a seed bed ready for planting. These floating gardens (baira) which are cultivated in the rainy season and float above monsoon floods are now becoming popular in many other areas in the south of Bangladesh. Figure 12.2 shows the practical application of floating water garden in coastal region of Bangladesh.
7. Farm machinery operations
   After harvesting of transplanted aman rice the turnaround time left for growing rabi crops is very short. With the desiccation of the soil deep and wide cracks develop and the surface soil becomes very hard and makes tillage operations difficult with traditional plough. Rapid and deep tillage reduces soil salinity by breaking the capillary continuity for upward movement of saline groundwater. Therefore, light mechanized tillage implements such as power tillers should be used to increase the speed and depth of tillage operation. With the climate change, the traditional field operations in agriculture must be substituted by farm machines to expedite operations smoothly. At the end of aman seasons, lands will go dry at s faster rate with the rise of temperature leaving a very small period of time for land preparation of the next crop by traditional equipment like local plows. Using tractors or power tillers this problem could be avoided and land can be prepared swiftly and timely for the next crop. Likewise, reapers help quick harvest of crops to save them from changed bad weathers and also the labor costs. Other farm machineries like seeder, reaper, weeder, thresher, winnower, drier etc. could be used for economic and timely agricultural operations (Roy et al. 2006). Deep tillage enhances rapid drifting of moisture from the soil

Fig. 12.2 Floating vegetable garden (Baira). *Source*: James Pander (2007)

to make it dry quickly requiring supply of water for seed germination and for seedlings. Minimum or zero tillage practices can be of very useful operation after transplanted aman harvest in areas of high water scarcity. Appropriate seeders/transplanters can be used for the operation.

Furthermore, a number of interesting adaptation measures have been promoted and subsequently applied in the southwestern region of Bangladesh under a project titled Reducing Vulnerability to Climate Change (RVCC). The project was implemented in six southwestern Districts of Bangladesh from 2002 to 2005, and it applied a few agricultural adaptation measures in a bid to reduce vulnerability of communities to climate change by increasing people's coping capacity (RVCC 2003; Schaerer and Ahmed 2004). The agricultural adaptations are worth special mention, due primarily to their simplicity and overall social acceptance. Table 12.5 highlights the agricultural adaptation measures considered under the project.

Whatever adaptation strategy is adopted, however, it should start with and be led by the local community wherever possible for it is local village people who are often the real experts on climate change. Rather than implementing highly technical, expensive and outsider-led interventions that are often untried in field conditions, priority should be given to using and modified traditional coping mechanisms developed in the communities in Bangladesh and around the world.

Table 12.5 Strategic approaches considered for agricultural adaptation for the RVCC project

Strategy	Measure	Brief description of measure
Household level strategies in agriculture (crop, fishery, agro-forestry, and livestock)		
Increase food through agriculture	Drought tolerant crops/vegetables	Introduction of drought tolerant crops such as groundnuts, watermelon, etc.
	Floating gardens	Cultivation of vegetables on floating beds of water hyacinth (hydroponics)
	Low-cost irrigation	Demonstration of treadle pump and other simple technologies for irrigation
	Homestead gardening	Cultivation of vegetables and fruits on homestead plots for consumption and market
	Saline tolerant non-rice crops	Introduction of saline tolerant varieties of chili, mustard, maize and potato
Increase income through alternative livelihoods	Embankment cropping	Cultivation of beans, gourds, okra and other vegetables on embankments surrounding prawn ghers (ponds)
	Integrated farming systems	Using small area of land, small water body, and surrounding embankments to produce rice, fish and vegetables
	Cage aquaculture	Small-scale fish farming in cages, implemented in household ponds or common water bodies
	Nursery and homestead afforestation	Establishment of community nurseries and distribution (with handling instructions) of indigenous varieties of tree saplings (mango, coconut, sofeda, korai, guava, mehaguni, neem, kewra, etc.) to beneficiaries for homestead planting
	Saline tolerant tree plantation	Planting of saline tolerant fruit and timber trees for longer term income generation
	Mele (reed) cultivation	Cultivation of reeds used to produce mats that are widely used for sitting and to sleep on

Source: Modified from Schaerer and Ahmed (2004)

12.5 Conclusion and Recommendations

Bangladesh is an agro-based country. Agriculture contributes 22.7 % to GDP (BBS 2005). With the sea level rise, a vast land in the southern coastal belt will go under water and salinity will grasp new land areas. This will reduce the existing crop area severely, thereby hampering agricultural productions. Obviously, the densely populated country may face acute food shortage to feed her people. Cultivation of rice, a stable food, has suffered most, while the production of wheat, pulses, rape seed and coconut has also been affected by climate change.

According to the IPCC, southern part of Bangladesh is slated to lose the largest amount of cultivated land globally due to rising sea level. A 1 m rise in sea levels would inundate 20 % of country's landmass. Prolonged inundation, increased drought, salinity and loss of land due to erosion are the enhanced risks that agriculture is facing due to climate change. Increased drought and salinization in the dry season and prolonged inundation in the wet season will change the areas suitable for growing crops. Since agriculture is the mainstay for the economy, Bangladesh is very sensitive to impacts of climate change on the agricultural sector of coastal zone of Bangladesh.

Agricultural development in the saline coastal belt of Bangladesh is constrained by various physical, chemical and social factors. Water and soil salinity are among the most dominant limiting factors in the region, especially during the dry season. Soil salinity affects many crops including rice, the most important, at different levels and at critical stages of growth. As a consequence, yields can be reduced and in severe cases total yield is lost. The presence of salinity in surface and ground water in different areas near the coast is another factor affecting crop production. In spite of these difficulties, in some places it has shown that an integrated agricultural management system involving multiple crops as well as aquaculture is doing well in the coastal areas. This study shows that the integrated systems are productive and efficient and, in general, the level of sustainability in these areas is the highest of all systems that were studied.

The findings of this study will be transmitted to local authorities in Bangladesh with the hope that they will enable agricultural policy making departments to plan management actions for sustainable agricultural development in the coastal regions.

Some of the recommendations are as follows:

1. It is recommended that an indicator-based analysis be one method by which the sustainability level of different agricultural systems be assessed. The information thus gained can be used as one factor for determining coastal agricultural policy of Bangladesh.
2. The coastal population of Bangladesh is dependent on agriculture for income and employment. Therefore, government should emphasize introducing agricultural practices that ensure productivity and employment.
3. Comprehensive investigation is needed to understand the present agricultural practices and to bring diversification in the agricultural system for reducing yield gaps.
4. There is a need to design and enforce a policy and institutional framework for natural resources management and conservation to support agricultural growth in the coastal areas of Bangladesh.
5. Improving physical and social infrastructure—roads, electricity, communication, water and sanitation, health and education—in rural areas is fundamental for sustainable development in agriculture.
6. Proper operation of embankments should be ensured for protecting agriculture from saline water and storm surges.
7. Rainwater should be stored in the saline-affected water areas to minimize the salinity effect of the surface water during the dry season.
8. Introduction of integrated agricultural system by storing rainwater in saline affected areas may be a news strategy to cope with emerging adverse situations.
9. Government should formulate a project to promote the feasibility of integrated agricultural system in the salinity-affected areas of Bangladesh to ensure the sustainability of coastal agriculture.

Acknowledgements The first author gratefully acknowledges support from the Japan Society for the Promotion of Science (JSPS) of Japan in the conduct of this research.

References

ADB (1994) Climate change in Asia: Bangladesh country report. Asian Development Bank (ADB), Manila

Agrawala S, Ota T, Ahmed AU, Smith J, van Aalst M (2003) Development and climate change in Bangladesh: focus on coastal flooding and the Sunderbans. Organization for Economic Co-operation and Development (OECD)

Ahmad M (2003) Coastal livelihood: situation and context. Working paper WP015. Program Development Office for Integrated Coastal Zone Management Plan Project, Water Resources Planning Organization, Dhaka, pp 1–30

Ahmed AU (2000) Adaptability of Bangladesh's crop agriculture to climate change: possibilities and limitations. Asia Pacific J Environ Dev 7(1):71–93

Ahmed AU, Schaerer C (2004) Sustaining livelihoods opportunities for the coastal poor under climate change: a case study from Bangladesh. In: Anonymous (ed) Proceedings of coastal zone Asia Pacific, Brisbane, 7–9 September 2004

Ahmed AU, Alam M, Rahman AA (1998) Adaptation to climate change in Bangladesh: future outlook. In: Huq S, Karim Z, Asaduzzaman M, Mahtab F (eds) Vulnerability and adaptation to climate change for Bangladesh. Kluwer, Dordrecht, pp 125–143

Alam SMN, Phillips MJ (2004) Coastal shrimp aquaculture systems in southwestern Bangladesh. Asian Fish Sci 17:175–189

Ali AMS (2004) Technological change in agriculture and land degradation in Bangladesh: a case study. Land Degrad Dev 15(3):283–298

Ali SMA (2006) Rice to shrimp: land use/land cover changes and soil degradation in southwestern Bangladesh. Land Use Policy (Elsevier) 23(4):421–435

Asaduzzaman M, Reazuddin M, Ahmed AU (eds) (1997) Global climate change: Bangladesh episode. Department of Environment, Government of Bangladesh, Dhaka (July)

BBS (Bangladesh Bureau of Statistics) (2011) Population and housing census report 2011. Bangladesh Bureau of Statistics, Ministry of Planning, Dhaka

BBS (Bangladesh Bureau of Statistics) (2005) Statistical Year Book of Bangladesh. Ministry of Planning, Government of the People's Republic of Bangladesh. Dhaka, Bangladesh

BCAS-RA-Approtech (1994) Vulnerability of Bangladesh to climate change and sea level rise: concepts and tools for calculating risk in integrated coastal zone management (Summary report, Main reports and institutional report). Bangladesh Centre for Advanced Studies (BCAS), Resource Analysis (RA), and Approtech Consultants Ltd., Dhaka

BCCAAP (Bangladesh Climate Change Strategy and Action Plan) (2010) Ministry of Environment and Forest (MOEF), Government of People's Republic of Bangladesh, Dhaka

BPRSP (Bangladesh: Poverty Reduction Strategy Paper) (2005). General economics division. Planning Commission, Government of People's Republic of Bangladesh, Dhaka

BUP-CEARS-CRU (1994) Bangladesh: greenhouse effect and climate change. Briefing Documents No. 1-7. Bangladesh Unnayan Parishad (BUP), Centre for environmental and Resource Studies (CEARS), University of Waikato, New Zealand and Climate Research Unit (CRU), University of East Anglia, Norwich

CCC (2009) Adaptive crop agriculture including innovative farming practices in the coastal zone of Bangladesh. Climate Change Cell, DoE, MoEF; Component 4b, CDMP, MoFDM, Dhaka (June)

CEGIS (2006) Impacts of sea level rise on landuse suitability and adaptation options. Draft final report. Submitted to the Ministry of Environment and Forests, Government of Bangladesh and

United Nations Development Programme (UNDP) by Centre for Environmental Geographic Information Services (CEGIS), Dhaka
Chowdhury QS, Hossain Q (2006) Bengal delta in Banglapedia. National Encyclopedia of Bangladesh, Asiatic Society of Bangladesh, Dhaka
Deb AK (1998) Fake blue evolution: environmental and socio-economic impact of shrimp culture in the coastal areas of Bangladesh. Ocean Coast Manag 41(1):63–88
DoF (Department of Fisheries) (1995) Shrimp resources statistics. Central Shrimp Cell, Department of Fisheries, Dhaka
DoF (Department of Fisheries) (2004) Draft shrimp strategy, summary. Department of Fisheries, Dhaka
DoF (Department of Fisheries) (2005) Fishery statistical yearbook of Bangladesh 2003–2004. Fisheries Resources Survey System, Department of Fisheries, Dhaka
DoF (Department of Fisheries) (2010) Fishery statistical yearbook of Bangladesh 2009–2010. Fisheries Resources Survey System, Department of Fisheries, Dhaka
GoB (Government of Bangladesh) and UNDP Bangladesh (2009) Policy study on the probable impacts of climate change on poverty and economic growth and the options of coping with adverse effect of climate change in Bangladesh. General Economic Division, Planning Commission, Dhaka, Bangladesh
GoB and UNDP (2005) National Adaptation Programme of Action (NAPA), Final report: November 2005. Ministry of Environment and Forests, Government of the People's Republic of Bangladesh (GoB), and United Nations Development Programme (UNDP), Dhaka, 48 pp
Habibullah M, Ahmed AU, Karim Z (1998) Assessment of foodgrain production loss due to climate induced enhanced soil salinity. In: Huq S, Karim Z, Asaduzzaman M, Mahtab F (eds) Vulnerability and adaptation to climate change for Bangladesh. Kluwer Academic, Dordrecht, pp 55–70
Hagler M (1997) Shrimp: the devastating delicacy, a Greenpeace report. Available at: http://archive.greenpeace.org/oceans/shrimpaquaculture/shrimpreport.html. Accessed 12 Feb 2012
Hamid AM, Alauddin M (1998) Coming out of their homesteads: employment for rural women in shrimp aquaculture in coastal Bangladesh. Int J Soc Econ 25:314–337
Haque AKE (2004) Sanitary and phyto-sanitary barriers to trade and its impact on the environment: the case of shrimp farming in Bangladesh. IUCN Bangladesh Country Office, Dhaka, p 63
Huq S, Ahmed AU, Koudstaal R (1996) Vulnerability of Bangladesh to climate change and sea level rise. In: Downing TE (ed) Climate Change and World Food Security. NATO ASI Series, I 37. Springer, Berlin, pp 347–379
Huq S, Karim Z, Asaduzzaman M, Mahtab F (eds) (1998) Vulnerability and adaptation to climate change for Bangladesh. Kluwer, Dordrecht, 135
IPCC (1998) The regional impacts of climate change: an assessment of vulnerability. Cambridge University Press, Cambridge
IPCC (2001) Climate change 2001: impacts, adaptations, and vulnerability. In: McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS (eds) Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge
Islam A (1999) Effects of shrimp farming on the physico-chemical and biological qualities of water. Bangladesh Agricultural University, Mymensingh
Islam MR, Ahmad M (2004) Living in the coast: problems, opportunities and challenges. Program Development Office for Integrated Coastal Zone Management Plan Project; Water Resources Planning Organization. Dhaka, Bangladesh
Islam MR, Koudstaal R (2003) Coastal zone management: an analysis of different policy documents. Working paper 09. Program Development Office for ICZM, p 52
Islam MR, Ahmad M, Huq H, Osman MS (2006) State of the coast 2006. Program Development Office for Integrated Coastal Zone Management Plan Project, Water Resources Planning Organization, Dhaka

James Pander (2007) Community-led adaptation in Bangladesh. 2nd International workshop on community based adaptation to climate change, Dhaka, Bangladesh

Karim M, Stellwagen J (1998) Shrimp aquaculture. Final report, Fourth Fisheries Project, Department of Fisheries, Dhaka, 6, p 101

Karim Z, Hussain SG, Ahmed AU (1998) Climate change vulnerability of crop agriculture. In: Huq S, Karim Z, Asaduzzaman M, Mahtab F (eds) Vulnerability and adaptation to climate change for Bangladesh. Kluwer Academic Publishers, Dordrecht, pp 39–54

Mahmood N (2006) Prawan (Changri). Banglapedia – the National Encyclopedia of Bangladesh. Asiatic Society of Bangladesh, Dhaka

Mahtab F (1989) Effect of climate change and sea level rise on Bangladesh. For Expert Group on Climate Change and Sea Level Rise. Commonwealth Secretariat, London

MoWR (Ministry of Water Resources) (2005) Coastal zone policy. Ministry of Water Resources, Government of the People's Republic of Bangladesh, Dhaka

PDO-ICZMP (2003) Coastal livelihoods – situation and context. Programme Development Office for Integrated Coastal Zone Management Plan, Dhaka

Rashid EH, Kabir B (1998) Case study: Bangladesh, water resources and population pressures in the Ganges river basin: water and population dynamics. In: Sherbinin AD, Dompka V, Bromley L (eds) Case studies and policy implications and foreword by Malin Falkenmark. Available at: http://www.aaas.org/international/ehn/waterpop/front.htm. Accessed 20 Mar 2012

Roy KC, Sattar MA, Rashid MH, Ahmed S, Wohab MA, Amain M, Matin MA (2006) Developed agricultural machinery (in Bangali). Farm Machinery and Post Harvest Process Engineering Division, BARI, Joydebpur, Gazipur, Bangladesh. pp. 1–48

RVCC (2003) Report of a community level vulnerability assessment conducted in Southwest Bangladesh. A report prepared by the Reducing Vulnerability to Climate Change (RVCC) Project, CARE Bangladesh, Dhaka

SRDI (Soil Resource Development Institute) (1997) Land and soil resources use guideline. Kaliganj *upazila*. Satkhira District. Government of Bangladesh

SRDI (Soil Resource Development Institute) (2001) Land and soil resources use guideline. Shyamanagar *upazila*. Satkhira District. Government of Bangladesh

Schaerer C, Ahmed AU (2004) Adaptation to climate change in vulnerable communities: lessons from practice in southwestern Bangladesh. In: Ahmed AU, Haque N (eds) Adaptation to climate change: knowledge sharing for capacity building. Proceedings of workshop held on 10 December 2003 at COP 9 Milan. Climate Action Network South Asia (CANSA) and RVCC, Dhaka

Shamsuddoha M, Chowdhury KR (2007) Climate change impact and disaster vulnerabilities in the coastal areas of Bangladesh. COAST Trust and Equity and Justice Working Group, Dhaka

WARPO (Water Resources Planning Organization) (2006) Coastal development strategy. Ministry of Water Resources, Government of the People's Republic of Bangladesh

Warrick RA, Ahmad QK (eds) (1996) The implications of climate and sea-level change for Bangladesh. Kluwer Academic Publishers, Dordrecht, Boston, London, 415 pp

WB (2000) Bangladesh: climate change and sustainable development. Report no. 21104-BD. Rural Development Unit, South Asia Region, The World Bank (WB), Dhaka, p 95

William W, Gravgaard A-K (2010) Bangladesh fights for survival against climate change. The Washington Times. Pulitzercenter.org. Available at: http://pulitzercenter.org/articles/bangladesh-fights-survival-against-climate-change. Accessed 7 Mar 2010

Chapter 13
Livelihood Adaptation in the Drought Prone Areas of Bangladesh

Umma Habiba, Abu Wali Raghib Hassan, and Rajib Shaw

Abstract Droughts are very frequent in Bangladesh due to its geo-physical position and varying rainfall pattern. Drought is considered as devastating and causing substantial damage and loss to agriculture and allied sectors. Particularly the northwestern livelihood experiences its noteworthy impact on their daily because of the consequence of drought impacts. More specifically, agriculture, health and social life are badly affected by drought. Despite drought vulnerabilities, a large number of actors have been involved in developing and implementing adaptation strategies to reduce the vulnerabilities. However, to adapt with drought, livelihoods in this region have been developing and using various practices mainly through agronomic management, crop intensification, water resource exploitation, etc. Although, livelihood based adaptation is person centric solution based on both local-knowledge with scientific facilitation and it is dual-way process that builds on the adaptive capacity through a systematic process. Moreover, livelihood adaptations actions may not sufficient enough for reducing drought risk that caused by climatic variability and climate change considerably. It requires greater institutional capacity at all levels of government and more efficient coordination between different levels of government. With this regards, this chapter serves as a basis for understanding drought impacts and to scale up viable adaptation options in the drought-prone areas of Northwest Bangladesh. In conclusion, this chapter emphasizes on the development of successful drought adaptation actions that would be performed through national to local level and helps livelihoods to build resilience against drought in future.

U. Habiba (✉) • R. Shaw
Graduate School of Global Environmental Studies, Kyoto University, Kyoto, Japan
e-mail: shimuagri@yahoo.com

A.W.R. Hassan
Department of Agricultural Extension, Ministry of Agriculture, Dhaka, Bangladesh

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*,
Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_13,

Keywords Adaptation • Drought • Institutional capacity • Livelihood • Northwest Bangladesh

13.1 Introduction

It is revealed that adverse effects of climate stimuli including variability and extreme events in the overall development of Bangladesh would be significant and highly related to the changes in water sector. The National Adaptation Programme of Action (NAPA) (2005) highlights that water related impacts of climate change to be amongst the most critical for Bangladesh, particularly in relation to riverine and coastal flooding, but also in relation to increase winter droughts in some areas (MoEF 2005) The whole area of Bangladesh is more or less prone to adverse impacts of climate change. But in terms of drought, the North and North-western areas are particularly sensitive due to geo-climatic and human induced conditions. Droughts in this area are not only experienced through high rainfall variability accompanied with high temperature, but also groundwater depletion, lack of canal and river dragging, increased population, deforestation, etc. accelerate drought severity in this region (Habiba 2012).

Whatever happens to climate, it subsequently affects various other sectors. All these are important, because, these affect the lives and livelihood of the people. Hence, the impacts on livelihood depend on the nature and severity of the physical impacts relating to agriculture, water availability and quality, disaster-proneness, hospitability of the physical environment due to rising temperature and changing water regimes to pathogenic activity. However, it has been seen in drought affected areas that the livelihoods are extremely distressed by drought situation. More specifically, agriculture, health and social life are badly affected by drought (Habiba et al. 2012). To adapt with drought, livelihoods have been adapting various practices mainly through agronomic management, crop intensification, water resource exploitation, etc. Likewise, Ahmed and Chowdhury in 2006 mentioned four major types of adaptive practices: (a) traditional responses (e.g. pond and *dighi* excavation, retention of rainwater in *khari* and canals, shedding, tillage, breaking top soil), (b) state supported responses (e.g. DTW facilitated irrigation), (c) alternative responses (e.g. adoption of mango farming, orchard developing), and (d) some domestic responses (e.g. alternative livestock and poultry/birds rearing) are existing in this drought affected region. As livelihood strategies consist of a range and combination of activities and choices that helps people to achieve their livelihood goals, therefore, several studies of livelihoods sources, at the household level, broadly classify livelihood strategies as agricultural intensification, diversification and migration (Valentine 1993; Adams and He 1995; Dercon and Krishnan 1996; Barrett et al. 2001; Galab et al. 2002; Adugna 2005; Berehanu 2007).

Despite recurrent drought events, the above mentioned livelihood adaptations actions may not sufficient enough for reducing drought risk that caused by climatic variability and climate change considerably. Because, livelihood based adaptation is person centric solution based on both local-knowledge with scientific facilitation and it is dual-way process that builds on the adaptive capacity through a systematic process. Adding together, livelihood adaptation may be defined as the continuous process of changes to livelihoods (assets and activities) which either enhance existing security and wealth or try to reduce vulnerability and poverty (Davies and Hossain 1997).

With this contrast, the main purpose of the book chapter is to disclose the overall situation of drought in northwestern region of Bangladesh, livelihood vulnerabilities towards drought and how livelihoods in this region deal with insidious disaster by adopting various adaptation strategies. In conclusion, it recommends various adaptation options of livelihood which need to be institutionalized by various levels and tailored through national level to local level in a sustainable way.

13.2 Physio-Geographic Environment and Framework Conditions

13.2.1 Geographical Location

In Bangladesh, the Barind (upland of Northwestern part) has been experiencing drought conditions for the last two to three decades. According to Banglapedia (2006), this area is designated as the most drought-prone areas (Fig. 13.1). Geographically, this area extends from 24°22′N to 24°73′N latitude and 88°20′E to 88°36′E longitude mainly covering Barind Tract, Punarbhava floodplain and Ganges river flood plain area. This drought-prone region covers most part of the greater Dinajpur, Rangpur, Pabna, Rajshahi, Chapai Nawabganj, Bogra, Joypurhat and Naogaon district.

After severely drought affected Northwestern region, Southwestern part of Bangladesh is also facing drought impacts. But, the severity of drought in this region is moderate. Among Southwestern region, mainly Jhenaidah, Jessore and Satkhira districts experiences drought during the dry season.

13.2.2 Topography

The topography of drought affected region is mainly flat with an average elevation of 25 m above the mean sea level. The surface geology in a major part of the area is composed of uplifted terraces of Pleistocene sediments called Barind Tracts (Fig. 13.2). These are more strongly weathered than the surrounding alluvium. In areas with alluvial, the Barind Tract sediments can be found at depths of the order of 150–200 m or more.

Moreover, the western part of this area composed of flood plain soil which is depressed area and inundates from average year flooding due to spillage of riverbanks.

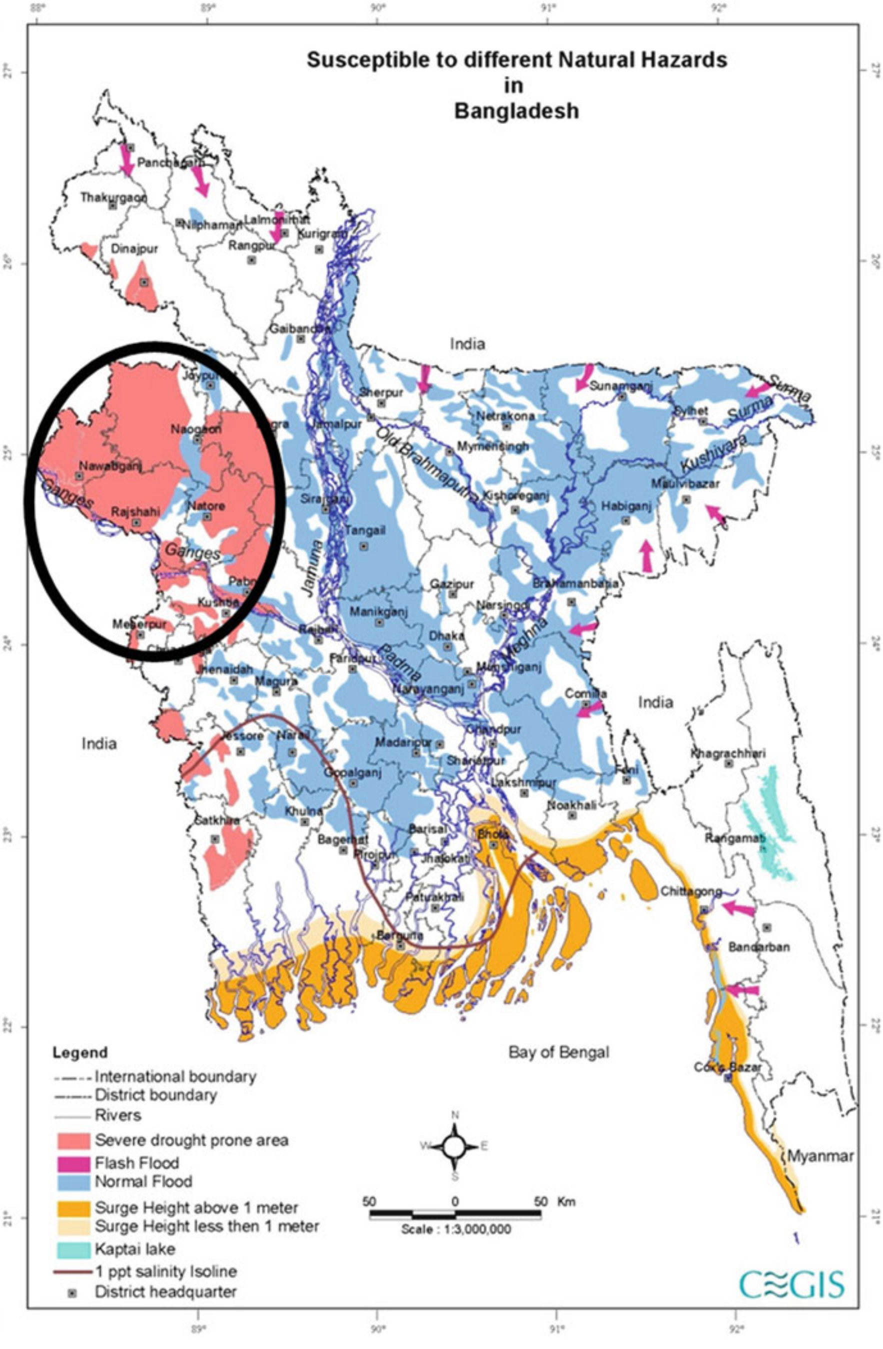


Fig. 13.1 Drought-prone area in Bangladesh. *Source*: CEGIS (2012)

Fig. 13.2 Undulated land in Barind tract. *Source*: Barind Multipurpose Development Authority (2010)

13.2.3 Physiography

Physiographically this region is divided into three units. These are Recent Alluvial Fan, Barind Pleistocene, and Recent Floodplain. These morphologic units are separated by long, narrow bands of recent alluvium. The floodplain of the Mahananda flanks located at the west side while the Karatoya delineates the eastern margin. The Punarbhaba, Atrai and Old Jamuna with headwaters in the foothills of the Himalayas have cut across the Pleistocene and their floodplains separate the units. These and numerous other streams are responsible for the development of a broad Piedmont alluvial plain, which delineates the northern flank of the Tract. The Tista alluvial fan is located to the north of the area. This fan surface of the Himalayan foothills has a slope of approximately 0.43 m/km and it overlaps the Barind, which has essentially a flat or somewhat domed surface. South of the Barind Tract are the Recent Floodplains, with a southerly slope of about 0.06 m/km.

13.2.4 Lithology

In Northwestern region, spatial distributions and thickness of the upper silt and clay unit does not exist where very fine to fine sands generally occur at the surface (Shamsudduha et al. 2011). Moreover, shallow aquifers occur at relatively deeper (>15 m below ground level) depths in the Barind Tracts where the upper silt and clay unit is thick. Therefore, a number of bore log information is available in the Northwestern areas, which are mainly drilled by Bangladesh Water Development Board (BWDB), Bangladesh Agricultural Development Corporation (BADC) and Barind Multipurpose Development Authority (BMDA). The logs cover a depth ranges from 40 to 300 m in different location. Most of the bore logs identified in the Porsha and Saphar upazila of Naogaon district shows that the properties of upper layer is of plastic clay up to 30 m and in the lower part it is consists of coarse to fine sand. Plastic clay is sedimentary in origin. Old rivers and streams washed kaolinite (formed from decomposed granite) from its parent rock. As the streams flowed from upland areas the kaolinite mixed with other clay minerals, sands, gravels and vegetation before settling in low-lying basins to form overlaying seams of plastic clay. Brown clay with silt is observed in Gomastapur and Nachole upazila of Chapai Nawabganj district mainly in the upper layer and medium to coarse sand is found in the lower part. Topsoil of the area is mainly composed of clay material indicating low percolation rate as well as low moisture holding capacity. Recharge characteristics is also poor in this area due to slow percolation rate from soils.

13.2.5 Climatic Condition

According to Global Circulation Model (GCM) results predict an average temperature increase in Bangladesh due to climate change of 1.0 °C by 2030 and 1.4 °C by 2050. Though monsoon precipitation is likely to increase by 6.8 % by 2050, the distribution patterns of precipitation during the growing season, high temperature and higher rates of evapotranspiration will create further water stress conditions and a decline in agricultural production in drought-prone areas. Adding together, the presence of Tropic of Cancer at the south, this drought-prone area in Northwestern region is summer dominated hemisphere. This region is generally warm and humid prevailing with very little rainfall and the weather remains hot by the daytime but becomes cooler by late night. Therefore, most of the droughts primarily occurred in pre-monsoon (March–May) and post-monsoon (October–November) seasons, but in some extreme cases the pre-monsoon droughts have extended in monsoon season due to delayed onset of the monsoon rains, e.g. 1979 drought (Choudhury et al. 2003). However, rainfall is comparatively little in this region with annual average rainfall varying between 1,400 and 1,900 mm (Shahid 2011). Almost 87 % of rainfalls occur during the monsoon season and 13 % of rainfalls occur during the dry season. Rainfall also varies widely from year to year and area to area. For instance, in 2000 the total annual rainfall of this area was 1,690 mm whereas in 2009 it went down to 793 mm. On the contrary, in 2006 the annual total rainfall of Bangladesh was 2,178 mm whereas in drought prone areas it was 1,193 mm (Habiba et al. 2011) (Fig. 13.3). Therefore, it has been seen from Fig. 13.3 that the difference between the annual total rainfalls of drought affected region and the entire Bangladesh is around 1,000 mm.

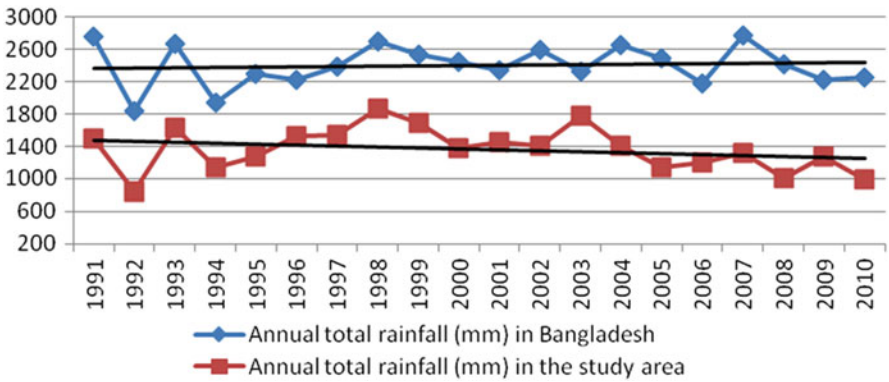


Fig. 13.3 Annual total rainfall of drought-prone areas from 1991 to 2010. *Source*: Data collected from Bangladesh Meteorological Department (2012)

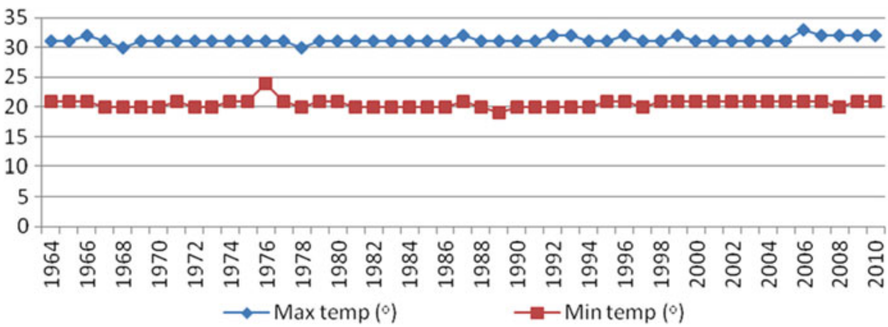


Fig. 13.4 Average annual maximum and minimum temperature in Rajshahi district. *Source*: Data collected from Bangladesh Meteorological Department (2011)

In terms of temperature, comparatively high temperature exists in this area. The mean temperature ranges from 25 °C to 35 °C in the hottest season and 9 °C to 15 °C in the coolest season. The temperature too often exceeds 40 °C in this region (Hassan 2012). Even, in summer season, some of the hottest days experience a temperature of about 45 °C or even more in Northwestern area, particularly in Lalpur upazila (sub-district) of Natore district (Banglapedia). In winter season, the temperature goes down to 5 °C in some places in Dinajpur and Rangpur districts. Figure 13.4 shows average annual maximum and minimum temperatures of one of drought affected district that located at the Northwestern region of Bangladesh. From this figure, it has been seen that the average annual minimum and maximum temperature lies between 20 °C and 32 °C in this area, respectively. Therefore, this older alluvium region experiences extremes than the rest of the country.

13.2.6 Soil

The undulating uplands with red/yellow clay soils of Northwestern Bangladesh is known as Barind Tract which is considered as one of the low output zones in terms of agricultural production. This tract belongs to an old alluvial formation which is usually composed of massive argillaceous beds of pale reddish brown color that often turns yellowish on weathering. Lime nodules and pisolitic ferruginous concretions occur throughout the soil. The soils are clay-clayey loam and loam. The top and sub soil is generally clay to loam and substratum is dominantly clay soil. Locally the soils are rich in lime. Soil p^H varies between 6.0 and 7.5. Soils are deficient in nitrogen and phosphorus.

13.2.7 Water Resources

The Northwestern region is bounded by the Jamuna (Brahmaputra) river to the east and the Ganges River to the south. Major rivers of North West Region are Teesta, Upper-Karatoya, Atrai, C. Jamuneswari, Karatoya and Bangali. Moreover, there are several minor rivers in this area. Besides this, ponds, beels, khari (khari is lengthy pond like structure to a length of 2–3 km with a width varying from 10 to 15 m) and canals (natural canals which have potentials for conserving water and providing water for irrigation and other purposes) are the larger water bodies, which is generally connected to the rivers during monsoon season. Most of the rivers of this region flow from very steep to flat ground. Huge flow is available in the Brahmaputra and in the Ganges during monsoon compared to the dry season flow. But due to the consequence of climate change as well as drought, the water bodies in these areas are going dry, river beds are filled in with sand, and water flow in the river is decreasing. Therefore, during dry season, the surface water is almost empty everywhere and groundwater is the main source of irrigation and other domestic uses.

13.2.8 Groundwater Table

The aquifer system in the Northwestern region of Bangladesh comprises quaternary to recent sediments. The surface geology includes Holocene Piedmont Deposits in the Northwestern part of the region, Holocene instream Deposits and the Madhupur Clays of the Barind areas in the central and Southwestern part of the region. On a regional basis, following three aquifers have been identified (UNDP-BWDB 1982).

- An upper layer composed of silts and clays, which acts as semi-confining layer. The thickness of this layer is variable but does not exceed 10 m in the majority of the region. Although the thickness is locally in excess of 20 m in high Barind area and 50 m in the southern part of Dinajpur district. A gradual thickening of the layer occurs towards the southern part of the region where maximum thickness ranges from 10 to 20 m.

- A composite aquifer, which is composed of very fine to fine sands and which overlies the main aquifer. Its thickness varies from only one meter in the northwest to over 30 m in the Atrai basin. The composite aquifer is a major source for village water supply wells and for hand tube wells.
- Main aquifer, which is composed of medium to coarse sands and which has excellent water transmitting properties. The exploited thickness of the aquifer ranges from less than 10 m in parts of Bogra district to over 60 m in the Northwest. Aquifer conditions are found to be good in most parts of the Teesta, Brahmaputra–Jamuna and Ganges river floodplains and on the Old Himalayan Piedmont plain. Potential aquifers are not found in high Barind area.

In most areas, the lower two aquifers are probably hydraulically interconnected. The main aquifer, in most of the area, is either semi-confined or leaky or consists of stratified, interconnected, unconfined water-bearing zones which are subject to delayed drainage. Recharge to the aquifer is predominantly derived from deep percolation of rain and flood water.

In the Northwest region of Bangladesh, groundwater is being used mainly to meet the irrigation as well as domestic demands. A large number of deep and shallow tube wells have been installed in connection with different groundwater based irrigation project. Installation of deep tubewell in Barind area is another notable irrigation project by Barind Multipurpose Development Authority (BMDA) in this area. About 13,000 deep tube well are using in Barind area to fetch underground water daily for irrigating boro crops. Besides these, private initiatives has also flourished and now playing a significant role in irrigation development.

13.2.9 Agriculture Land Use

Agricultural land use and cropping pattern in drought-prone region has tremendously been changed over time due to the introduction of Barind Integrated Area Development Project (BIADP) in mid-1980s. Before that this area is known as mono cropped area. Farmers depended only on monsoon rainfall and used traditional irrigation equipments like seuti, done, sawing basket to irrigate the crop from surface water source. But, after the expansion of BIADP activity through the installation of DTW (Deep Tube Well), irrigation was started through groundwater to facilitate to grow boro crops and other winter vegetables in this region during the dry season. As a consequence of irrigation facilities along with large-scale adoption of modern rice varieties, this region shows almost doubled its food grain production during the last two decades (Selvaraju and Stephan 2007). Figure 13.5 represents that boro cultivation area is gradually increased than the previous year compared to aus and aman rice of this area. It also helps farmers to adapt with this emerging adverse situation that occurred through drought during the dry season.

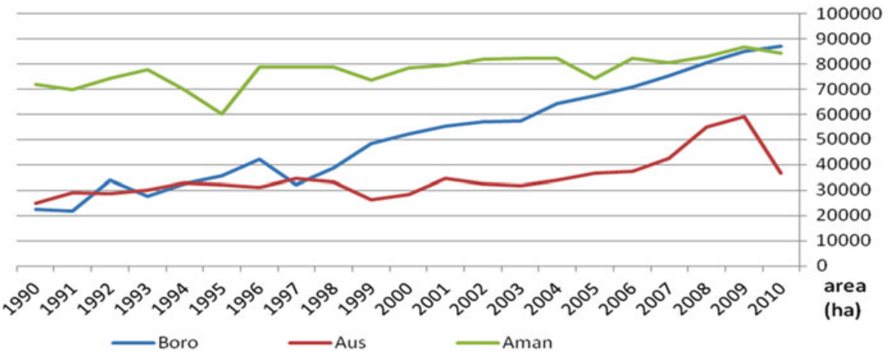


Fig. 13.5 Expansion of boro cultivated area compare to aus and aman coverage in drought affected area from 1990 to 2010. *Source*: Author

13.3 Vulnerability of Livelihoods

As a consequence of drought impacts, the poor people and women, particularly the fishermen, wage earners, and small and marginal farmers are extremely vulnerable because of lack of capacity and awareness. Thus it ultimately affects lives and livelihoods of the people in the drought affected region. Although, it has been seen that livelihood in drought affected Northwestern region mostly depends on agriculture for their survival. Therefore, different degrees of vulnerabilities happen due to frequency and severity of drought that affects crop production and makes livelihood distress in terms of social and economical point of view. In this section, how rural people's life's and daily livelihoods pattern are substantially affected by drought results would be discussed.

13.3.1 In Terms of Agriculture

Climatic variability particularly the erratic temperature, shortage of rainfall, high evaporation rate and the overriding drought situation make the overall agriculture vulnerable. Agriculture, being a means of livelihood in drought prone Northwestern Bangladesh. Almost two third of the population depends on agriculture that contributes Bangladesh's most important economic sector. The production of aus, boro rice, winter vegetables and fruits including several varieties of mangoes have been affected by increased variations in rainfall, dry spells, temperature and drought occurrence. Major droughts occurred in 1966, 1969, 1973, 1978, 1979, 1981, 1982, 1989, 1992, 1994, 1995, 1998, 2000, 2006 and 2009 causing substantial reduction in food production and affecting rural livelihoods. Among them, the consecutive droughts of 1978 and 1979 directly affected 42 % of cultivated land and reduced rice production by an estimated 2 million tons (Brammer 1987). Past droughts have typically affected about 47 % of the country and 53 % of the population (WARPO 2005). Karim (1995) highlighted that a severe drought resulted in an immense loss of agricultural production and affected approximately 2,000 people and 50,000 people in 1978–1979 and 1989, respectively. Furthermore, the 1997 drought caused a reduction of around 1 million tons of food grain, of which about 0.6 million tons were transplanted *aman*. Moreover, it is reported that every year 0.45 million ha of land is affected by very severe drought during rabi season while 0.40 and 0.34 million ha of land are affected during pre-kharif and kharif seasons, respectively [there are three cropping seasons in Bangladesh locally known as pre-kharif (16 March–30 June), kharif (1 July–15 October) and rabi (16 October–15 March)] (Climate Change Cell 2009). Furthermore, Rahman et al. (2008) mentioned that drought in 2006 caused 25–30 % crop reduction in Northwestern part of Bangladesh. As agricultural production has decreased in many of the drought affected years, hence, most of the people suffer from food security, malnutrition and livelihood insecurity.

13.3.2 In Terms of Fisheries

The frequency of extreme droughts has a disproportionate effect on fish habitat and populations, and the incidence of diseases is expected to rise. Drought causes drying up of surface water bodies like canals, ponds, beels and rivers, etc. It also hinders fishing activities and causes difficulties for the fishing dependent livelihood. It is reported by Haque (2007) that seasonal variations of rainfall and temperature have diverse implications on fishing, hatchery operations, fish production and livelihoods of a wide range of people directly and indirectly involved with fisheries and aquaculture. Furthermore, drought causes loss of biodiversity and extinction of some fish species.

13.3.3 In Terms of Livestock

Livestock are affected by air temperature, humidity, wind speed, and thermal radiation, which influence their growth, milk production, reproduction, health, and well-being. Moreover, due to lack of grazing facilities and shortage of food that makes unfavorable environment for the livestock. Sometimes, cattle and poultry suffer from heat stroke, even affected by different diseases like black quarter, anthrax, and so on. Drought also diminishes the reproductive capacity of cattle and poultry. Thus, it causes economic loss for the livestock dependent livelihood in drought affected areas.

13.3.4 In Terms of Social Life

Drought not only creates vulnerabilities for agriculture, fisheries and livestock sector, but also causes difficulties for rural livelihood. It has tremendous impact on social lives. During this period, food consumption along with food purchasing capacity is reduced due to the lack of sufficient food production and the increase of food price. Women in rural livelihood usually cut down their daily food consumption. Moreover, people are facing safe drinking water problems during drought period and woman's hardship is increased due to fetch drinking water from far distances. Even, sometimes conflictions among the neighborhoods arise due to the scarcity of water during the drought period. Children are unwilling to go to school, so that during this period dropout increases rather than other periods. Besides, agricultural labor has no work to do agricultural activities in their land. They act as daily labor during this period. Even in extreme conditions, farmers change their occupation and go to nearby village or city to look for some jobs to meet household's basic demands. In severe cases, seasonal migration happens in this area.

13.3.5 In Terms of Health

Livelihood in drought affected areas tremendously faces hotter temperature. Different diseases like dysentery, diarrhoea, dengue and hypertension arises in this area. Excess mortality during heat waves is greatest in the elderly people and those with the pre-existing illness (Sator et al. 1995; Semenza et al. 1999; Kilbourne 1997). Much of this excess mortality from heat waves is related to cardiovascular, cerebro-vascular and respiratory diseases. Heat stroke, heat exhaustion and some respiratory problems increase due to high air temperature (Semenza et al. 1999). On the other hand, due to the lack of safe drinking water, people in this area uses pond water that also leads to various water-borne diseases.

13.3.6 In Terms of Environment

Drought causes the environmental degradation in various ways. It dries out the natural water bodies and thus causes loss of wild and cultural stocks. It reduces water levels in reservoirs, lakes, and ponds, increases salt concentration, water temperature, affects air and water quality and degrades landscape quality and causes soil erosion. On the contrary, drought has substantial effect on ground aquifer. Surface water as well as groundwater is the main source of fresh water in drought-prone Northwestern region of Bangladesh. The dependency of livelihood on groundwater has increased since the last decade due to the excessive utilization of groundwater for irrigation purposes. Not only excessive use of groundwater for irrigation purposes but also domestic uses cause depletion of groundwater level during the dry season in Northwest Bangladesh (Habiba et al. 2011). This causes a great threat to the irrigated agricultural system and also causes draw down of groundwater level and leads to environmental problems such as heavy metal contamination, arsenic and salinity.

Besides ground aquifer, drought also acts as a catalyst of land degradation that causes reduction of soil moisture and water retention capacity. It enhances the drying out of topsoil and effective loss of soil structure and aggregation. Moreover, drought declines soil organic contents, reduce microbial activity and overexploitation of sparse vegetation. On the other hand, it causes loss of biodiversity by hampering the microbial activities, extinction of some species and damage to plant and animal species, increase incidence of the diseases by bringing pathogen and parasites.

13.4 Adaptation Responses Towards Drought in Northwestern Bangladesh

Despite drought vulnerabilities, a large number of actors have been involved in developing and implementing adaptation strategies to reduce the vulnerabilities. Because, adaptation can greatly reduce vulnerability by making communities better able to adjust the climatic variability as well as drought, moderating potential damages and helping them to cope with adverse consequences. Hence, this section illustrates the existing adaptation responses of different levels that are undertaken in the drought-prone area of Bangladesh.

13.4.1 Adaptive Responses at Local Level

Farmers are the frontline of facing drought vulnerabilities; therefore, they have developed a wide range of adaptation strategies to cope with drought. In this regards, agronomic management is the key adaptation measure that helps to improve agricultural productivity. Thus, the common agronomic practices observed in this area are manuring and composting, seedbed method; ail lifting, tillage and shedding. These practices help to improve soil quality, add organic matter into the soil, hold rainwater during the rainy time and distribute rainwater uniformly into their cropping field. Mahoo et al. (2007) also mentioned that farmer's adopted tillage methods, agronomic practices and crop diversification approaches help to maximize yield from available water.

Crop intensification through crop diversification, cropping pattern etc. is another well accepted adaptive practice in drought affected Northwestern Bangladesh. Orindi and Eriksen (2005) and Adger et al. (2003) reported that farmers diversify crop types as a way of spreading risks on the farm. Therefore, majority of farmers in this area have adopted diversified crops like sugarcane, different type pulse and

Fig. 13.6 Rice and mango intercropping in drought affected area of Bangladesh. *Source*: LACC project, DAE, Bangladesh

oil crops, vegetables and different fruit crops like mango, jujube etc. in their cropping field to cope with drought. Even though, they are cultivating two crops in the same cropping field. For instance, rice and mango is a common adaptation practice in Northwestern Bangladesh that not only helps to minimize the yield loss happened through drought, but also adds economic benefits for the farmer's (Fig. 13.6).

Water harvesting through re-excavation of pond, khari, dam, mini ditch and canal is another adaptive practice performed by farmers in this area. But the percentage is comparatively lower than the other adaptive practice currently farmers are doing. Apart from the water harvesting, farmers utilized various type of water resources exploitation through deep tube well (DTW), shallow tube well (STW), low lift pump (LLP) etc. Figure 13.7 represents that farmers are withdrawing water through STW and using plastic pipe to distribute the water into their crop field.

In contrast with agricultural adaptive practices, different farmers group in drought affected areas utilize other income generating activities like business, wage labor, services and construction works etc. and other non-agricultural farming like rearing livestock, poultry, dairy farm, cattle fattening, fish culture, making cow dung fuel etc. It has been evident from Fig. 13.8 that farmers are using various adopting various practices in drought affected areas. Even, in the extreme drought periods, they took money from *mohajon* at high rate of interest and sometimes

Fig. 13.7 Irrigation provided in the cultivated field through shallow tube well (*left*) and plastic pipe (*right*). *Source*: Author

Fig. 13.8 Photos showing farmers income generating activities like mango and jiggery production in drought affected area. *Source*: Author

mortgaged their land and other household assets like ornaments, utensils, etc. Drought victims in Bangladesh were obliged to borrow money and food and/or sell their land and other belongings (Paul 1998).

13.4.2 Adaptive Responses at Institutional Level

Many countries are already adapting to current climatic events at different spatial scales—National, Provincial/State, district and local levels, and over different time frames—short term, mid-term, and long-term. In Bangladesh, it has been seen that government of Bangladesh (GoB) undertakes relief measures by providing drinking water, food grains and food subsidies to special groups through food-for-work programs for drought risk reduction. The rural works program of the Government of Bangladesh (GoB) provides employment to the population affected by drought

Table 13.1 Development of drought tolerant crop varieties by research institute in Bangladesh

Serial number	Name of drought tolerant crop variety	Developed technology
1	Barley	BARI Barley-6
2	Pulse crop	BARI Chola-5, BARI Mungbean lines BMX-01007
3	Rice	BRRI DHAN-56 and BRRI DHAN-57

and helps to mitigate the drought severity. To meet the increased demand for food; the government, research institute and NGOs have initiated modern agricultural technology and practices such as High Yielding Variety (HYV) seeds, increased irrigation coverage, and introducing drought tolerant varieties. Among them, Department of Agricultural Extension (DAE) provides some training programs to the farmers on how to use supplementary irrigation in T. Aman crops, alternate wetting and drying (AWD) method for rice crops; quality seeds production, collection and distribution at farmer's level.

In addition, LACC (Livelihood Adaptation to Climate Change) project is jointly implemented by Food and Agriculture of United Nations and the DAE (Department of Agricultural Extension), under Comprehensive Disaster Management Programme (CDMP) of Ministry of Food and Disaster Management where they executed different viable adaptation options for drought areas and found various adaptation practices beneficial for the livelihood such as mini ponds for rain water harvesting, homestead gardening, mango and jujube cultivation, etc.

Besides, Bangladesh Agricultural Research Institution (BARI), Bangladesh Rice Research Institution (BRRI) has developed some drought tolerant crop varieties and distributed the varieties to the farmers by DAE (Table 13.1). Even in 2009, government offered 100 h free irrigation for millions of farmers to pump underground water after a severe lack of monsoon rains.

Government also carried out irrigation facilities in drought affected northwestern region though *Barind* Multipurpose Development Authority (BMDA). The *Barind* Integrated Area Development Project (BIADP), later renamed as BMDA that was established in 1985 to retain environmental balance and check the desertification of the *Barind* region's Rajshahi, Naogaon and Chapai Nawabganj districts. Before the project activities started, the *Barind* Tract was the most unfavorable agricultural section of the country where rain fed local *T. aman* was the dominant crop. Now, the ensured supply of deep tube well (DTW) irrigation has fundamentally changed the *Barind* Tract's agricultural scenario. Because, BMDA has successfully expanded their executing area through construction of cross dams and water control structures; re-excavation of canals and ponds; installation of DTWs; afforestation; improve surface water augmentation; construction of irrigation canals and roads; electric connections for the DTWs; drinking water supply through the over head tank and production of fine and aromatic rice. Figure 13.9 shows BMDA activity in drought affected region of Bangladesh.

Likewise, several governmental agencies like Bangladesh Agricultural Development Corporation (BADC) and Rural Development Academy (RDA) has undertaken irrigation project in drought affected areas. On the other hand, Disaster

Fig. 13.9 Distribution of irrigation water into crop field through DTW (*left*) and irrigation channel (*right*)

Management Bureau (DMB), Department of Relief (DoR), Ministry of Environment and Forests (MoEF), Department of Environment (DoE), Ministry of Agriculture (MoA), Department of Livestock (DoL), Department of Fisheries (DoF) and different NGO's are also involved in the process of drought risk management.

13.5 Scale Up Suitable Adaptation Action to Minimize the Drought Risk of Rural Livelihood

Successful climate change adaptation by farmers will hinge on the availability of effective adaptation strategies and the extent to which those strategies can be implemented (Howden et al. 2007). As discussed in earlier that a wide range of adaptation strategies exists at the local level along with government and a number of organizations are trying to assist the drought victims by providing various facilities such as irrigation water, relief, seeds, etc. Although adaptation is not a straightforward process and adaptive actions depend on the farming system's adaptive capacity, and farmer's willingness to adopt one or more of the available adaptation strategies (Howden et al. 2007; Crimp et al. 2010). Moreover, based on the values, attitude, goals, beliefs and risk perception of livelihood, it is urgent to scale up the adaptation actions that helps the rural livelihoods to handle with the upcoming drought events.

With this context, the Livelihood Adaptation to Climate Change (LACC) project started its operation in the drought prone Northwestern Bangladesh (2005–2010) executed by Department of Agricultural Extension (DAE), Ministry of Agriculture, and technically guided by the Food and Agriculture Organization (FAO). The project implemented activities to promote livelihood adaptation and reduce vulnerability to climate change of poor communities who have the lowest capacity to adapt. At the same time, this project tested different adaptation options (Table 13.2) and evaluated these options by technical implementation working groups (*source*: ADPC 2006). They considered several criteria to prioritize these adaptation options.

Table 13.2 Assessment of adaptation options for their effectiveness, current state and future prospects

Sl. no.	Categories	Adaptation practice	Water availability situation	Effectiveness/ feasibility	Current state of implementation and/or requirements for improvement	Priority for future incremental action
1	Agronomic management	Seedbed method for T. aman rice	Rain fed	High	Not existing	High
2		Manures and composting	Rain fed and irrigated	Medium	Not followed widely due to non-availability of raw materials	Medium
3		Depth of transplanting for T. aman	Rain fed and irrigated	Low	Not tried yet	Low
4		Weed control reduce water seepage	Rain fed and irrigated	Medium	Followed only to control weeds, not to close soil cracks	Low
5		Manual closing of soil cracks	Rain fed and irrigated	Low	Sometimes followed, but not widely practiced as labor intensive	Low
6		Strengthening field bunds	Rain fed and irrigated	Medium	Sometimes followed, but not widely practiced	Medium
7	Water harvesting	Re-excavation of traditional ponds	Rain fed	High	Not followed regularly	High
8		Re-excavation of khari, canals	Rain fed	High	Needs social persuasion and policy advocacy, institutional support is required	High
9		Canals	Rain fed	Medium	Implemented in places close to river	Low
10		Water control structure	Rain fed	Medium	Some efforts met with limited success, needs community involvement	Low
11		Mini-ponds	Rain fed	High	Poor dissemination, needs institutional support	High
12		Supplemental irrigation	Rain fed	Medium	Already practiced widely	Low

13	Water resources exploitation	Shallow and deep tube wells	Rain fed	Medium	Implemented in many villages, but not in all villages	Medium
14		System of rice intensification	Rain fed and irrigated	Medium	Not widely practiced; but evaluated intensively, showed high level of yield increase and water savings	Medium
15		Direct sown rice (Drum seeder)	Irrigated	Medium	Not practiced, cost intensive and weeding becomes a problem	Medium
16		Drought resistant rice varieties	Rain fed and irrigated	High	Not widely accepted by the farmers as they prefer traditional varieties; needs extra efforts to disseminate short duration drought resistant varieties so as to fit a residual crop after T. aman	High
17(a)	Crop intensification	Green Manure–T. aman system	Rain fed	Medium	Not practiced; dissemination is very poor	Medium
(b)		T. Aus–Chini Atap system	Rain fed	Medium	Practiced in one of the villages, needs wider dissemination	Medium
(c)		T. aman–Mustard/Linseed system	Rain fed	High	Practiced in some places, needs further expansion, promising results expected	High
(d)		T. aman–Chickpea	Rain fed	Medium	Followed in low Barind areas, Some research is required to identify high temperature tolerant chick pea varieties	Medium

(continued)

Table 13.2 (continued)

Sl. no.	Categories	Adaptation practice	Water availability situation	Effectiveness/ feasibility	Current state of implementation and/or requirements for improvement	Priority for future incremental action
(e)		T. aman–Mung Bean	Rain fed	High	Not followed widely; DAE is advocating a short duration Mung bean variety; promising results expected	High
(f)		Famine reserve crops	Rain fed	Medium	Not practiced widely	Medium
18	Alternative enterprises	Mango cultivation	Rain fed and irrigated	High	Already spreading widely, but needs some scientific intervention such as introducing drought resistant varieties	High
19		Homestead gardens	Rain fed and irrigated	High	Followed occasionally, poor combination of crops. Not structured model gardens with drought resistant crops	High
20		Mulberry intercropping in rice	Rain fed	Medium	Not practiced in pilot areas, but is promising for the future in Barind areas, requires institutional support	Medium
21		Fodder cultivation	Rain fed	High	Not followed due to lack of awareness, identification of drought tolerant fodder crop is required	High

22		Fish cultivation in mini ponds	Rain fed and irrigated	Low	Not practiced, water availability is very poor	Low
23		Cottage industries	Rain fed and irrigated	High	Not systematically followed due to lack of institutional support	High
24		Manufacturing industries	Rain fed and irrigated	Medium	Not systematically followed due to lack of institutional support	Medium
25	Alternative energy source	Community based bio-gas and tree planting	Rain fed and irrigated	High	Limited implementation, but needs to be promoted with institutional support	High
26		Post harvest practices	Rain fed	High	Limited use at local level	High

Source: LACC project, DAE, Bangladesh

Table 13.3 Viable and suitable adaptation practices of livelihoods towards drought

	Name of the suitable adaptation practice
1	Alternative seedbed method for T. aman rice to manage variability in rainfall pattern
2	Re-exavation of traditional ponds to collect excess rain water and to use as supplemental irrigation during intermittent drought at community level
3	Exavation of mini ponds to store rain water and re-use during drought at farm level
4	Cultivation of drought resistant varieties of rice and other crops to improve the productivity and also to increase nutritional security
5	Crop intensification by adopting T. aman–Mustard/linseed cropping system to use the residual moisture after T. aman rice
6	Crop intensification by adopting T. aman–Mung bean cropping system to utilize the residual moisture after T. aman rice
7	Promoting mango cultivation in Barind Tracts to increase income and to mitigate seasonal drought
8	Establishment of model homestead gardens
9	Fodder cultivation
10	Promoting cottage industries as an alternative income generating activities
11	Promoting community based bio-gas and tree planting in drought prone areas
12	Advocating post harvest practices to maintain good quality seeds

Among them, drought mitigation potential, suitability and sustainability under future climate change conditions, relevancy to vulnerable communities, employment opportunities, gender integration and social acceptability are notable. However, 12 adaptation practices were identified by that project as viable and possed high level of priority for future incremental action at community level to mitigate future drought impacts (Table 13.3).

Apart from these viable adaptation actions, Habiba (2012) carried out an intensive research in 14 upazila (sub-district) of two severe droughts prone district namely Rajshahi and Chapai Nawabganj in Northwestern Bangladesh. It considered irrigated and non-irrigated village of each upazila by using a semi-structured questionnaire that mainly focuses on various adaptation practices of farmers toward drought. It serves as viable action- and implementation-oriented tool for making an upazila resilient to drought disaster. Therefore, the results came from this research highlight a total of 30 drought adaptive practices, 15 originated from irrigated village and 15 from non-irrigated village of that area at each upazila level. Table 13.4 shows farmer's recommended and prioritized drought adaptive practices (DAP) in both irrigated and non-irrigated areas.

13.6 Conclusions and Recommendations

Climate changes are predicted to lead an increase in storms, flood, and landslides and also increased prolonged dry spells (IPCC 2007). Climate change will affect agriculture through higher temperatures and more variable rainfall, with substantial

Table 13.4 Farmers' recommended top-most priority drought adaptive practices

	Prioritized drought adaptive practices at community level	
	Irrigated area	Non-irrigated area
1	Expected more drought information from TV, radio	Expected more drought information from TV, radio
2	Dairy farm establishment	Community savings and credit system
3	Community health care service for better care	Community health care service for better care
4	Establish dairy farm as income generating activities	Establish dairy farm as income generating activities
5	Save money	Save money
6	Sell agricultural goods during drought period	Sell agricultural goods during drought period
7	Public awareness program related to drought	Public awareness program related to drought
8	Extension worker's support for drought mitigation	Extension worker's support for drought mitigation
9	Cash as a support from institution	Electricity as a support from institution
10	Use of diesel for irrigation purposes	Use of diesel for irrigation purposes
11	Drag the river and use of river water	Drag the river and use of river water
12	Establishment of drought information center in union level	Establish drought information center at union level
13	Use of plastic pipe for supplemental irrigation	Use of plastic pipe for supplemental irrigation
14	Vegetable gardening	Vegetable gardening
15	Establish mango orchard	Establish mango orchard

reductions in precipitation likely in the mid-latitudes where agriculture is already precarious and often dependent on irrigation. As Bangladesh is an agrarian country, therefore, any fluctuation that happens through climate change as well as drought, it hampers country's economy and food insecurity.

Many structural/physical and institutional adaptation mechanisms have been implemented in the past through conventional top-down approach. However, they lack community participation and livelihood focus. Although, community is considered as the centre of disaster risk reduction and community actions make the disaster reduction most effectively. Therefore, community participation and control is essential for any successful implementation, orientation and maintenance of any disaster risk reduction project (Habiba and Shaw 2012). On the contrary, developing adaptation strategy requires a vision that balances the need to reduce climate change impacts with any constraints in national policy making processes. Because, farmers adaptive capacity does not automatically translate into successful adaptation to climate change (O'Brien et al. 2006). It requires greater institutional capacity at all levels of government and more efficient coordination between different levels of government.

It is evident from this study that livelihoods in Northwestern region are under severe threats from recurrent droughts. Over the years, these livelihoods have developed a number of mechanisms to cope with recurrent drought. Other players like the government and developmental partners have also developed and implemented interventions to help livelihoods adapt to these drought events and reduce their vulnerability. Unfortunately, these strategies are no longer adequate as the droughts have increased in frequency and magnitude. Thus, the prioritized adaptation options that came from farmer's and expert's point of view, it needs to be institutionalized by different levels. Because, better adaptation governance requires the capacities of communities and institutions to be enhanced to identify, prioritize and implement a wide variety of adaptation actions, policies and programs at local and national level (Prabhakar 2010). In addition, reduction of vulnerability of agriculture and allied sectors from the drought impacts, a suggested adaptation requires co-ordinate actions, proper planning, financial resources and community involvement. Therefore, the following consideration should be kept in mind to develop successful drought adaptation actions that would be performed through national to local level and helps livelihoods to build resilience against drought.

- Incorporation of livelihood adaptations in long-term planning
- Implementation of research and development on new crops
- Improvement of information dissemination network
- Market risk management in agriculture
- Access to credit
- Developing enabling institutions and favorable socio-economic conditions

Acknowledgements The first author highly acknowledges the support from GCOE-ARS Postdoctoral program of Kyoto University. The author specially thanks the Graduate School of Global Environmental Studies for supporting her research at Kyoto University, Japan.

References

Adams RH, He JJ (1995) Sources of income inequality and poverty in rural Pakistan. Research Report, No. 102. International Food Policy Research Institute, Washington, DC

Adger WN, Huq S, Brown K, Conway D, Hulme M (2003) Adaptation to climate change in the developing world. Prog Dev Stud 3:179–195

ADPC (Asian Disaster Preparedness Center) (2006) Report on option menu for livelihood adaptation to climate change and extension tool development. Climate change impact assessment and livelihood adaptation options in drought prone areas. DP9/1 BGD/01/004. ADPC, Bangkok

Adugna L (2005) The dynamics of livelihood diversification in Ethiopia revisited: evidence from panel data. Department of Economics, University of Massachusetts, Boston

Ahmed AK, Chowdhury EH (2006) Final report of "Study on livelihood systems assessment, vulnerable groups profiling and livelihood adaptation to climate hazard and long term climate change in drought prone areas of NW Bangladesh"

Banglapedia (2006) Drought in Bangladesh. http://banglapedia.search.com.bd/HT/D_0284.htm

Bangladesh Meteorological Department (2011) Abhawa Bhaban, Agargaon, Dhaka-1207 Bangladesh

Bangladesh Meteorological Department (2012) Abhawa Bhaban, Agargaon, Dhaka-1207 Bangladesh

Barind Multipurpose Development Authority (2010) Ministry of Agriculture. Dhaka, Bangladesh

Barrett CB, Reardon T, Webb P (2001) Non-farm income diversification and household livelihood strategies in rural Africa: concepts, dynamics, and policy implications. Food Policy 26:315–331

Berehanu E (2007) Livelihood strategies of smallholder farmers and income poverty in draught prone areas: the case of Gena-Bosa woreda, SNNPRS. MSc Thesis Presented to the School of Graduate Studies of Haramaya University

Brammer H (1987) Drought in Bangladesh: lessons for planners and administrators. Disasters 11(1)

Center for Environmental and Geographic Information Services (CEGIS) (2012) Dhaka 1212, Bangladesh

Choudhury AM, Quadirr DS, Neelormi S, Ahmed AU (2003) Bangladesh country report: assessment of vulnerability of water resources to climate variability and climate change. Report Submitted to Asia Pacific Network of Scientists Working on Global Change, Japan

Climate Change Cell (2009) Department of Environment, Ministry of Environment and Forests, Dhaka

Crimp SJ, Stokes CJ, Howden SM, Moore AD, Jacobs B, Brown PR, Ash AJ, Kokic P, Leith P (2010) Managing Murray-Darling Basin livestock systems in a variable and changing climate: challenges and opportunities. Rangeland J 32:293–304

Davies S, Hossain N (1997) Livelihood adaptation, public action and civil society: a review of the literature. IDS Working Paper 57, Institute of Development Studies, Brighton

Dercon S, Krishnan P (1996) Income portfolios in rural Ethiopia and Tanzania: choices and constraints. J Dev Stud 32(6):850–875

Galab S, Fenn B, Jones N, Raju DSR, Wilson I, Reddy MG (2002) Livelihood diversification in rural Andhra Pradesh: household asset portfolios and implications for poverty reduction. Working paper no. 34

Habiba (2012) Enhancement of drought risk management policy and actions incorporating farmer's adaptive practices in northwestern Bangladesh. Doctorate Thesis, Kyoto University, Kyoto

Habiba U, Shaw R (2012) Bangladesh experiences of community based disaster risk reduction. In: Shaw R (ed) Community, environment and disaster risk management, vol 10. Emerald Group Publishing Limited, Bingly, pp 91–111

Habiba U, Shaw R, Takeuchi Y (2011) Socio-economic impact of droughts in Bangladesh. Droughts in Asian monsoon region. In: Shaw R, Huy N (eds) Community, environment and disaster risk management, vol 8. Emerald Group Publishing Limited, Bingly, pp 25–48

Habiba U, Shaw R, Takeuchi Y (2012) Farmer's perception and adaptation practices to cope with drought: perspectives from northwestern Bangladesh. Int J Disaster Risk Reduct. doi:10.1016/j.ijdrr.2012.05.004

Haque MM (2007) Decentralized fish seed network in Northwest Bangladesh: impacts on rural livelihoods. PhD Thesis, Institute of Aquaculture, University of Sterling, Scotland

Hassan AWR (2012) Case study on drought and agriculture, Disaster and Climate Change Risk Management in Agriculture (DCCRMA) project document. Department of Agriculture (DAE), Khamar Bari, Farmgate, Dhaka

Howden SM, Soussana JF, Tubiello FN, Chhetri N, Dunlop M, Meinke H (2007) Adapting agriculture to climate change. Proc Natl Acad Sci USA 104:19691–19696

Intergovernmental Panel on Climate Change (IPCC) (2007) Climate change 2007: impacts, adaptation and variability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds). Cambridge University Press, Cambridge, UK

Karim N (1995) Disasters in Bangladesh. Nat Hazards 11:247–258

Kilbourne EM (1997) Heatwaves. In: Noji E (ed) The public health consequences of disasters. Oxford University Press, New York

Mahoo HF, Mkoga ZJ, Kasele SS, Igbadun HE, Hatibu N, Rao KPC, Lankaford B (2007) Productivity of water in agric: farmers' perceptions and practices. Int. Water Manage. Insti. (Comprehensive Assessment of Water Management in Agric. Discussion Paper 5), Colombo, Sri Lanka. ISBN: 978-92-9090-679-7

MOEF (Ministry of Environment and Forest) (2005) G.o.t.P.s.R.o.B. National Adaptation Programme of Action. Final Report, UNFCCC

NAPA (2005) National Adaptation Programme of Action (NAPA). Final report. Ministry of Environment and Forest, Government of the People's Republic of Bangladesh, Dhaka

O'Brien G, O'Keefe P, Rose J, Wisner B (2006) Climate change and disaster management. Disasters 30(1):64–80

Orindi VA, Eriksen S (2005) Mainstreaming adaptation to climate change in the dev. process in Uganda. Ecopolicy Series 15. African Centre for Technol. Studies (ACTS), Nairobi

Paul BK (1998) Coping mechanisms practiced by drought victims (1994/95) in North Bengal, Bangladesh. Appl Geogr 18:355–373

Prabhakar SVRK (2010) Promoting adaptation and disaster risk reduction in the post –kyoto climate regime. Climate change Adaptation and Disaster Risk Reduction: Issues and Challenges Community, Environment and Disaster Risk Management, Emerald Group Publishing Limited, 4:77–98

Rahman A, Alam M, Alam SS, Uzzaman MR, Rashid M, Rabbani G (2008) Risks, vulnerability and adaptation in Bangladesh. Human Development Report 2007/08, Human Development Report Office Occasional Paper, 2007/13

Sator F et al (1995) Temperature, ambient ozone levels, and mortality during summer 1994 in Belgium. Environ Res 70:105–113

Selvaraju R, Stephan B (2007) Climate variability and change: adaptation to drought in Bangladesh. A resource book and training guide. Asian Disaster Preparedness Center, Food and Agriculture Organization of the United Nations, Rome

Semenza JC et al (1999) Excess hospital admissions during the 1995 heat wave in Chicago. Am J Prevent Med 16:267–277

Shahid S (2011) Impact of climate change on irrigation water demand of dry season *Boro* rice in north-west Bangladesh. Climate Change 105:433–453

Shamsudduha M, Taylor RG, Ahmed KM, Zahid A (2011) The impact of intensive groundwater abstraction on recharge to a shallow regional aquifer system: evidence from Bangladesh. Hydrol J 19:901–916

UNDP-BWDB (1982) Ground-water-survey-technical report on hydrogeologic conditions of Bangladesh

Valentine T (1993) Drought, transfer entitlements, and income distribution: the Botswana experience. World Dev 21(1):109–126

WARPO (2005) National Adaptation Program of Action (NAPA): water, coastal areas, natural disaster and health sector. Water Resources Planning Organization (WARPO), Dhaka

Chapter 14
Coastal Livelihood Adaptation in Changing Climate: Bangladesh Experience of NAPA Priority Project Implementation

Mesbahul Alam, Ronju Ahammad, Paramesh Nandy, and Shahinur Rahman

Abstract Climate changes are increasing vulnerability of natural resource dependent livelihood practices of large population in Bangladesh. Extreme events such as cyclones, tidal surges, flood, river erosion and salinity stress have been severely affecting agriculture, fishing or fish cultivation and livestock rearing. Communities remain extremely vulnerable to disasters that impeded the key livelihoods in the coastal areas than any other place. The traditional agriculture cropping is decreasing in coastal areas due to variation of fresh water and salinity level and increasing abrupt weather events, tidal inundation and water logging. Large coastal population lacks of climatic information, improved crop varieties and diversified livelihoods to continue adaptation practices. In particular the marginalized and landless coastal people who have limited access to natural, social and institutional services of local govt. institutions are losing adaptive capacity in the long-run. The paper presents livelihood adaptation practices of coastal communities in Bangladesh. Particular emphasis is given on an innovative livelihood model-Forest, Fish and Fruit (Triple F) which shows integrated community based livelihood practices for short-, mid- and long-term adaptation. Drawing the discussion the paper highlights for improving the livelihood practices in a way that incorporates climatic risks in collective resource management and income generation enhance adaptive capacity of coastal community. Strengthening local institutional capacity to enabling collaboration between govt. departments and community effectively bring diversity of knowledge

M. Alam
Ministry of Disaster Management and Relief, Government of Bangladesh, Dhaka, Bangladesh

R. Ahammad • S. Rahman
Community Based Adaptation to Climate Change through Coastal Afforestation Project, UNDP, Dhaka, Bangladesh

P. Nandy (✉)
CBACC-Coastal Afforestation Project of UNDP-Bangladesh, Dhaka, Bangladesh
e-mail: pm.cbacc@gmail.com

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*, Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_14, © Springer Japan 2013

in climatic risk reduction measures, cost-effective implementation of the new adaptation technology and ensure social equity and empowerment in the access to livelihood resources. Collective livelihood practices can create pro-active attitudes, cross-learning opportunity and participatory decision-making which are important for claiming relevant govt. services, disseminating best experiences and facilitating adaptation practices across the community. Despite the fact, current adaptations will not supersede dynamic vulnerability of livelihoods in coastal areas to large extent due to multi-fetched threats and lack of sustainability in resource generation. The potential strength and weakness of adaptation innovations must be analyzed within immediate timeframe to address the short- to mid-term benefits for long-term policy making. More collaboration of local institutions and diverse stakeholders through enhancing the financial and technical capacity, and as a whole, inclusive governance are important for sustaining the livelihood resource benefits.

Keywords Climate change • Coastal community • Livelihoods • Triple F • Vulnerability

14.1 Introduction

Coastal communities are facing much more vulnerability across the globe (Shaw and Krishnamurthy 2012). Anthropogenic stress in terms of over exploitation of coral reef and fisheries and land based activities (i.e., agriculture intensification) already increased stress in natural system of the coasts. Climate change adds to lower recovery or resilience of the natural system for human well-being and livelihoods (Adger et al. 2005; Lebel 2012). Various nature and impacts of climate change shocks affect coastal livelihoods differently and govern vulnerability and adaptive capacity. Some of the disasters are fast in coastal areas in terms of its sudden affects to coastal life and livelihoods like tropical cyclone and storm surges, where others are slow in events like salinity or inundation increase, but these have long-term impacts on social and economic functions (Nicholls et al. 2007). The tropical cyclone of 2007 caused loss of valuable mangroves, social and physical resources and livelihood bases that post-disaster recovery has not yet been possible in Bangladesh (Mallick et al. 2011). With changing frequency of cyclonic wind and storm surges and inundation coastal agriculture and domestic fisheries and open fishing have been highly affected which are significant livelihoods sources to majority coastal people. Salinity level is slowly increasing over the time and causing serious threats to traditional agriculture farming and mangrove ecosystems (Moniruzzaman 2012).

High climate sensitive livelihood characteristics and different socio-economic level and access of community and households to assets determine adaptive capacity. Large coastal population is less capable to share the majority of the natural resources effectively in livelihood practices due to lack of effective coastal zone policy and regulation, collaborative resource management and local institutional capacity.

Social inequality in terms of limited resource ownership and external support affect adaptive capacity of particular poor and marginalized groups in coastal areas (Nandy and Ahammad 2012). Coastal development interventions largely focused on land stabilization, structural protection measures for disaster risk reduction (Agrawala et al. 2003) and by contrast, ignored embedded social construction and resource ownership legacy in changing climate (Nandy and Islam 2010). As result, long-term institutional inertia caused fragmented resource management which was neither integrative livelihood practices nor socially inclusive towards incorporating the emergent coastal adaptation in Bangladesh. Though protective engineering measures by building earth embankment reduced physical vulnerability to storm surges this was not planned and based on anticipatory impacts of climate change related stress like increased storm surge height and water logging on livelihood to adjust to current and future changes (Mallick et al. 2011). The paper mainly presents livelihood adaptation practices in coastal areas by drawing experiences of Bangladesh NAPA priority project implementation. Several adaptation practices are also discussed to understand the diversity of practices and strength towards long-term adaptation.

14.2 Climatic Vulnerability and Coastal Livelihood Adaptation

Climate related risks largely trigger extreme events and impacts on social and ecological systems in Bangladesh. Based on Intergovernmental Panel on Climate Change (IPCC) evidences of climatic risks in relation to coastal ecosystems Bangladesh has much emphasis on increased sea surface temperature; CO_2 concentration; change in storm frequency, intensity and track; altered wave and water runoff; and sea level rise (Nicholls et al. 2007). Increase sea surface temperature has already recognized for coral mortality and algal blooming. Coastal people substantially depend on sea and river fish for food and protein demand and only livelihoods in Bangladesh. There is another reason that sea surface temperature can damage coral reef of St Martin's Island in its south-east coastal zone. CO_2 concentration due to increased fertilization and decreases P^H are likely to change coral and mangrove habitat and optional livelihoods of adjacent coastal communities. Whereas coastal fisheries contribute to large scale protein food, understanding temperature impacts on fish catch and reproductive behavior in Bangladesh is yet to be satisfactory.

Changes in tropical cyclonic and storm surge events are highly consistent for Bangladesh based on different findings of the studies drawn in IPCC report. Increasing frequency of cyclonic wind and storm surges are recorded though IPCC findings show little variation of regional average to country context. Storm surges are relevant to climate change prediction for increase of extreme water level and height in Bangladesh though uncertainty of origin and impacts remains a critical issue. Storm surges cause serious flooding and structural failure to loss of livelihoods. Altered wave rate and relationship is not correctly assessed in country scale though erosion and accretion is a continuous process in Bangladesh. Regional context of sediment run off is assessed for 40 large deltas which lead Bangladesh at risk to altered sediment flow, water quality and nutrient supply in mangroves and aquatic habitats.

Sea level rise is among others the critical threat which can trigger associated climate changes to extremely vulnerable coastal ecosystems of Bangladesh. The large deltaic plain of Ganges–Brahmaputra–Meghna rivers receive sediment flow that increase subsidence. Natural compaction of subsidence and upstream human activities (dam) are likely to enhance sea level rise in Bangladesh. The findings of subsidence and change of sediment flow is currently based on regional scale that Bangladesh are likely to be affected with sea level rise. Neither of the interconnection between subsidence rate and sea level rise is distinctively found, but the associated impacts are already observed and increasingly severe to affect the livelihoods.

There are relative variations of sea level rise at 10 cm, 20 cm to 1 m by 2030, 2050 and 2100 (Ali 1996). Scientific predictions may vary though upward water level in storms and tidal inundation (4–7.5 mm/year) in Bangladesh are plausible evidences of sea level rise in coastal areas. The key impacts of sea level rise in coastal ecosystems are large scale inundation, storm and flood damage and salt water intrusion. All the impacts have different degree of relation to vulnerability of coastal ecosystems in Bangladesh. In qualitative view, the impacts cause drainage congestion to embankment loss, ecological degradation of agriculture, wetlands and mangrove habitats, and social vulnerability to livelihoods. IPCC predictions of sea level rise may displace more than 1 million people by 2050 in Bangladesh.

14.2.1 Key Risks and Vulnerability of Coastal Livelihoods

Coastal ecosystems comprise diverse social and ecological features in Bangladesh. Natural and planted mangroves; newly accreted chars; agricultural lands; aquatic resources; human settlements; urban centers; and small and medium size business attributes shape the coastal ecosystems into highly dynamic confluence of human and environment. Agriculture practices cover the largest 59 % of total land use followed by shrimp, fisheries and wetlands (13 %), mangrove (11 %) and others including urban centres (17 %). Mangroves, one of the valuable functional ecosystems serves protection against disasters and produce benefits to coastal communities and national economy through forest products. Fisheries are the major concentration of social and institutional activities ever increasing due to population growth and subsistence demand for food and profit oriented business (i.e., shrimp farming) in coastal areas. Newly accreted Char land management is largely influencing social and ecological factors of the area due to its potential and multiple uses for afforestation, livelihood and human settlement. There has been estimated an increasing landmass accretion of 137,168 ha over erosion of 86,000 ha lands during a period from 1973 to 2000 (MES 2001). Between 1990 and 2005, almost 79,500 ha of accreted lands have been stabilized by mangrove plantation

(FAO 2010). In practice accretion of lands shaped coastal ecosystems into functional (land stabilization) and productive (agricultural practices, pastures) resource (Nandy and Islam 2010).

The diversity of coastal resources has different scales of functional capacity and roles to benefit coastal communities for livelihood and national economic growth. Long-term benefits of these multiple resource regime are even larger depending on the subsequent resource management capacity. Morphological shifting of coastal boundary and extreme events has threatened social and ecological functions in spatial and temporal scale. Over the time and space, coastal livelihoods have been vulnerable to extreme events in different ways. Morphological change caused land erosion hazard and social displacement of coastal communities. Tropical cyclone and storm surges already affected three coastal regions of the country with massive loss of life and property. The Bay of Bengal is the breeding ground of 40 % of the world cyclones and storm surges affecting coastline of Bangladesh. Nine cyclonic winds were recorded in the Bay of Bengal for 1991–2000 periods, almost of these affected the country in different scales (Hossain et al. 2012). The super cyclone 'Sidr' killed 3,500 people and destroyed human settlement, property and valuable mangrove resources in 2007. The associated social and economic impacts from the tropical cyclone and storm surge are however neither assessed, nor, documented for providing effective interventions.

Salinity intrusion is slow and steady event affecting the coastal ecosystems by degrading soil fertility, freshwater bodies and regeneration capacity of mangroves. Storm surges and sudden tidal inundation cause direct inland intrusion of salinity and destroy standing crops. Conversion of agricultural lands or mangroves for shrimp farming and salt pan already contributed to change of coastal ecosystem beyond threshold into undesirable states. Documented in many literatures salinity intrusion has received much discussion for large scale coverage in 32 % land areas of the country. The landward intrusion of salinity level puts coastal livelihoods at higher risks and has been extreme with climate change. About 70 % of the coastal lands are affected with salinity for particular 4–6 months in a year (Nandy et al. 2003). About 50 % of coastal lands are somewhat untenable for agriculture in a year. Rahman et al. (2011) noted that 50–60 % of summer and winter crop varieties declined due to salinity in south-western coastal districts from 1975 to 2006. They also identified loss of rice varieties and homestead forest species with salinity intrusion in terrestrial ecosystem.

Coastal flooding increase risks to livelihoods by sudden submersion in agriculture lands inside the coastal embankment. Storm surges usually create large scale flooding with rapid pace and impacts harvestable crops, freshwater ponds, and fisheries, and mangrove vegetation. Tidal inundation is a regular phenomenon though it becomes devastating with erratic heavy rainfall and cause monsoon flooding for 1–2 weeks. Observation shows that flooding or waterlogging from inundation is increasingly occuring 3–4 times in a year. Increase subsidence of rivers by sediment deposit decrease river navigation and subsequent withdrawal of excess water from the coastal areas. Drain out of excess water is often not possible due to imbalance water height between inner and outer part of the coastal embankment. Different studies referred to both natural water flow (erosion of land) and human actions (e.g., hill cutting) increase sediment deposit in different coastal points over the years. There is until inadequate assessment available in relation to the rate of subsidence and the possible interventions taken for effective drainage management.

14.2.2 Linking Livelihood and Adaptation

Livelihoods influence exposure and sensitivity to current and future climate change related stresses (Pouliotte et al. 2006). The principal and key determinant of adaptive capacity is related to the ability of livelihoods to withstand shocks and stresses which dominates the degree of livelihood risks. Any strategy to reduce vulnerability is based on understanding of how people currently sustain their livelihoods. The traditional natural resource oriented livelihood strategies is highly climate sensitive in coastal areas. Almost 80–90 % people depend on both agriculture and fisheries directly, or partly in any of these in different seasons for livelihoods. Climatic change related stress is creating surprises beyond community perception, access to information and capacity to take pre-planned adaptation measures. Lower productive lands and inequity in user groups and lack of access to external supports for additional livelihood measures is weakening coping capacity of coastal people, and so require adaptation measure. Coastal adaptation can be understood through adjustment of ecological, social, or economic systems to actual or expected climatic stimuli and their effects or impacts. Adaptation as a process can provide opportunities to prevailing capacity of individual and community for transforming into new livelihood approaches. Effective adaptation measures refer to identification of current livelihood problems and innovating policies and practices with respect to historical vulnerability trend line and considering future uncertainty.

Livelihood is interrelated with social, ecological and institutional drivers which imply innate capacity of coastal community that enables them or may not to adapt to changing situation. Social construction in resource ownership pattern and ecologically pre-determined physical risks can limit livelihood practices and adaptation processes in coastal areas. Avoiding social limits to continuous livelihood practices of majority coastal people are as important as to secure their household income and access to institutional services. External institutions have critical roles in developing any risk reduction policy while drawing cross-scale interplay of relevant stakeholders, and fit of new approaches at local level. Adaptation policy broadly includes international negotiation and funding process where national level can arrange priority based interventions for target people at risks, locally driven and accepted measures.

Protection and improvement of livelihood practices can provide additional and at the same time alternative means of adaptation practices. Depending on timing and purposes any of the adaptation, livelihood practices also vary within planned or autonomous; short to mid- and long-time interventions. Protection of coastal livelihoods is thought in most cases by building embankment and cyclone shelters which are hard adaptation measures. These adaptation interventions are yet to be adequately assessed with changing shock levels of increased storm surges and salinity intrusion as well as water logging. Adaptation of coastal communities or individual household needs innovative livelihood inputs which can be alternative to adjust to new shocks for maintaining their life supporting functions. The livelihood based adaptation in prolonged water logging or saline situation requires salinity tolerant rice varieties, fast growing fish cultivation or alternative land uses.

14.3 Experience of NAPA Priority Project

14.3.1 Multi-scale Adaptation through Forest, Fish and Fruit (Triple F Model)

The Community Based Adaptation to Climate Change through Coastal Afforestation (CBACC-CF) is the first priority project of NAPA Bangladesh that has introduced the Triple F livelihood model for enhancing adaptation capacity of coastal communities in Hatiya of Noakhali; Char Fassion of Bhola and Barguna Sadar of Barguna coastal districts (Fig. 14.1). Different livelihoods types including agriculture and fish cultivation, tree plantation and duck rearing are integrated in the model considering the salinity risks and freshwater scarcity in coastal areas. The basic structure for executing the model is preparation of ditch and dyke. Each ditch is 54 m length × 6 m width × 2 m depth and dyke is 60 m length × 3 m width × 2 m height. Ditch is suitable for irrigation and fresh water fish cultivation; dyke is cultivated with seasonal agricultural vegetables, improved fruit varieties and forest trees. In 1 ha of land, eight ditches and nine dykes can be constructed. Each family has been distributed one ditch and dyke and a total of 896 households will be involved in the Triple F model of the project.

Fish: Each ditch is suitable for fish culture with fast growing and improved varieties. Though coastal areas are dominated by fishermen groups, with changing extreme events, most of the people are losing seasonal fish catch from the sea and river. The ditch system can secure additional or alternative source of income through fish cultivation in two seasons of a year. By excavating a single ditch a family can produce an estimated 150–200 kg of fishes annually which secures their household protein and additional income after consumption. Harvesting of rain water in the ditches also supports regular water supply to plantations on dyke and increase fresh water security as it doubles as a reservoir.

Fruit trees: Dyke is planted with high yielding fruit varieties BAU-Kul (*Ziziphus mauritiana*) and BAU-Guava (*Psidium guajava*), developed with the technical support from the Fruit Tree Improvement Centre of Bangladesh Agriculture University (BAU). The significant feature of the fruit varieties is twice yielding in a year and

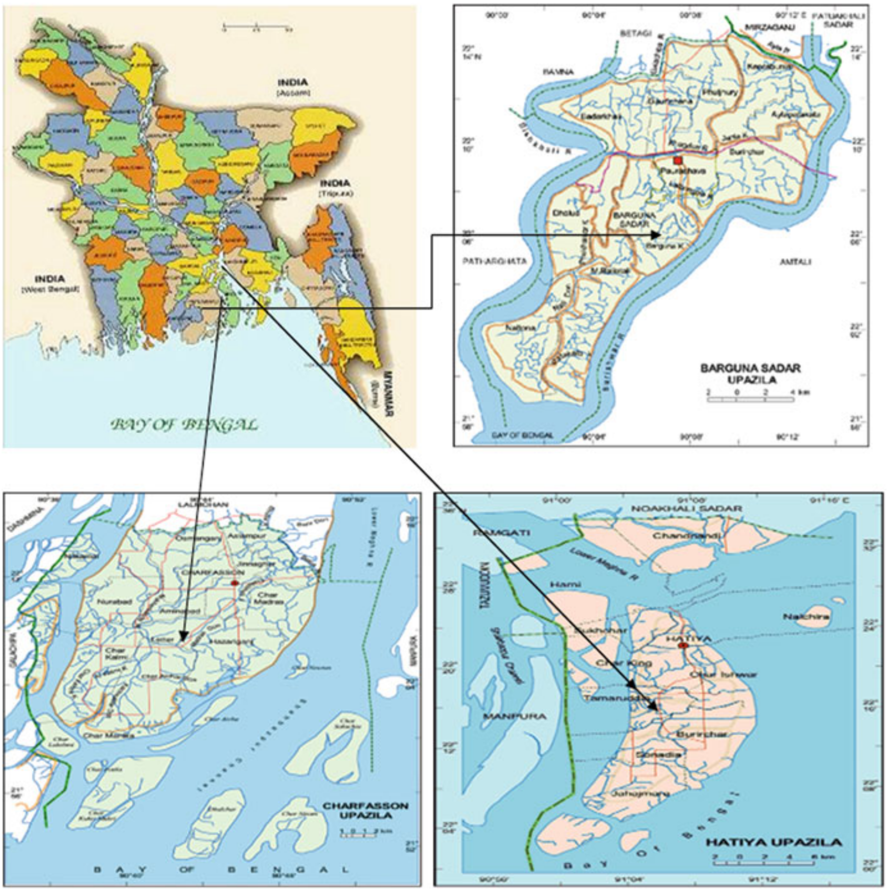


Fig. 14.1 Arrow indicated the potential sites of Triple F

enriched vitamin and mineral source in household food. On a dyke 24 seedlings (12 nos. of each variety) of these fruit varieties can be planted in between forest tree species. Fruiting starts in eight months of out planting on each dyke though sizeable harvesting of the fruit takes 2–3 years.

Forest trees: Different forest trees and palms (*Cocos nucifera*) are planted on dyke to provide communities with long-term timber, mid-term fuel-wood from branch pruning and food products. These add to the protection services of the Triple F model and the surrounding land and community from climatic impacts.

Fig. 14.2 Community based livelihood adaptation practices

14.3.1.1 Short-Term Adaptation Measures

Planting of improved varieties of vegetables on long top surface of each dyke provides immediate opportunity for household consumption of communities. Further expansion of the dyke area for cultivation is possible through special supporting arrangements (scaffolding) on the margins of the ditch to support hanging vegetables including; country bean, cucumber, bottle, bitter and sweet gourds (cucurbitaceous vegetables) and other creeper vegetables. Each family is currently cultivating six to seven types of leafy vegetables on the 60 m long and 3 m wide top surface of the each dyke (Fig. 14.2). In 6 months of dyke preparation for the model, each beneficiary has been capable to produce 80–100 kg of leafy vegetables which increase family income up to US$25 per month by selling vegetables after household intake.

It is apparent from Table 14.1 that each of the beneficiaries have generated more than BDT 35,000 (US$434) per year from adaptation interventions with Triple F model. The income ranges from BDT 23,000 to BDT 67,000 based on the performance of nursing and adequate management of own ditch and dyke. The best performers have been able to earn more than BDT 67,000 (US$827) per family/year from each ditch and dyke (Table 14.1) which is additional income in addition to previous routine livelihood activities of each beneficiary.

Among three types of adaptation measures in the model, aquaculture based intervention showed highly promising followed agriculture based adaptation measures. This may be associated with the fact that the area is dominated by the fishermen groups. Ditch is cultivated with fast growing and locally demanding fish varieties for solving regular protein food demand at household and economic benefit by additional sell at the local market. With the project support, a single ditch generates income up to US$300 per family from fish sell. Of the participated coastal families who depend on fishing or work as day labor in sea/riverboats for seasonal livelihoods (July–September) expect the ditch arrangement may be alternative adaptation practice. To the coastal families ditch system is highly preferred for rain water harvesting and cultivating fishes, irrigating dyke vegetation in even dry seasons.

Table 14.1 Enhancement of adaptive capacity through Triple F adaptation interventions (Nandy and Ahammad 2012)

Beneficiary groups	Annual income—before project (thousand BDT)	Income through adaptation intervention (thousand BDT) AP			Annual income—after project (thousand BDT)	Difference (thousand BDT)	Adaptive capacity ranking (H for high; M for moderate; L for low)
	a	AI1	AI2	AI3	b	a–b	
1	29.00	40.00	15.00	12.00	67.00	38.00	H
2	67.00	18.00	80.00	36.00	134.00	67.00	H
3	25.00		40.00	6.00	46.00	21.00	M
4	50.00	41.00	41.00	10.20	76.20	26.20	M
5	79.00	60.00	60.00	27.40	102.4	23.40	L
AV	50.00	24.50	47.20	18.32	85.12	35.12	–

AI adaptation interventions, *AI1* agriculture, *AI2* aquaculture, *AI3* livestock, *AV* average

14.3.1.2 Mid to Long-Term Adaptation Measures

Dyke system also comprises mid to long term adaptation options and creating mid-term income generation in 2–3 years with two high yielding fruit varieties *Z. mauritiania* and *P. guajava*. The significant feature of the fruit varieties is twice yielding in a year and enriched vitamin and mineral source in household food. Each family expects high potential yield and income profit from the fruit varieties. Each fruit variety produces 10–20 kg of fruit per tree and generates total income up to US$500 of a family per year. Coastal communities secure not only regular, short-term and mid-term alternative income options, but also planted forest species on dyke for long-term benefits.

Case study 1: Masura Begum (35 years) of Barguna, lost her little shelter by devastating Cyclone Sidr-2007. She says "I had sufferings of food. Now accessing to this Triple F model, I have learned how to feed my family not in a day, even in the next months with this project support. We spent 3–4 days without food and survived by eating green banana only. I got access to land and started producing different agriculture vegetables on the dyke, and fish in the ditch of the land. In the three months, I earned $150 USD by selling vegetables only after family consumption. I earned $250 USD from selling fish and eggs of duck supplied by the project. I do not need to buy any vegetable and fish for my family rather I am saving money from selling Triple F resources so that I could pay off my debts".

Case study 2: HasanGorami (29 years) of Barguna, used to sell his labor as a fisherman on big boats during the fishing seasons to support his family, while sits idle in most of the non-fishing seasons. He says "Now I maintain this ditch and dyke and this helps me earn extra money. I grew different vegetables on the top of the dykes and creepers on the scaffolding and various types of fish in the ditch. I already earned $ 300 USD from selling fish and vegetables and expect to double this by the end of the year".

14.3.2 Salt Tolerant Rice Cultivation

Agricultural practice is increasingly constrained with high level of salinity ingress and frequent and severe impacts of natural disasters in coastal areas. Given the impacts of seasonal water logging and salinity on land, and lack of irrigation in dry seasons, alternative cropping practice through use of climate resilient rice varieties have been a vital need for agricultural production in the area. The CBACC-CF project has introduced salt tolerant rice variety (BR 47) in four coastal districts. Considering lower land productivity, the rice variety has been found potential crop in coastal areas. The BR 47 variety has increased annual production from previously fallow and salinity affected lands and eventually fulfilled household food consumption (Fig. 14.3). Largely coastal people depend on the traditional rain fed *Aman* which is the single crop. The yield benefits from the demonstration reflect increasing people's

Fig. 14.3 Shifting single crop to double crop through introduction of salt tolerant rice variety

attention in coastal areas for cultivating additional land in subsequent years. In only one project site of Barguna sadar upazila, there is currently 500 ha of lands cultivated with the rice varieties in dry season (Nandy 2012).

The paddy has yielded three times more production compared to any local varieties for equal land unit. Most of the coastal farmers in the project areas are accepting the double cropping pattern with the new variety to reduce seasonal risks and adapt to food crisis. Otherwise, it is not possible to secure household foods only depending on traditional rice cropping. The cultivation of the BR 47 variety requires less water and has tolerance capacity to certain level of soil salinity in dry season (CBACC-CF 2012). There are additional economic benefits that farmers are receiving income by selling rice and seeds. Access to training of seasonal risk management, improved rice varieties and land use techniques is important for improving capacity building of the farmers in coastal areas. However, the initial cultivation of salt tolerant rice production system requires seed source and irrigation where external supports of extension services must be ensured.

14.3.3 High Yielding Fruit (Guava/Zuzubee)

Planting fruit species around homestead has been a traditional culture of rural community for household food consumption and small source of income. High yielding fruit varieties (*Z. mauritiana*, *P. guajava*) is recently introduced in coastal areas to maximize land use and secure food and income. Agricultural lands are often less suitable for crop farming due to too much of water or less water. People are cultivating additional fruit plants around homestead areas as well as raised bank of the cultivable lands and ponds. When agricultural lands are submerged with water it has been possible for cultivating high yielding fruit varieties on non-affected bank without any risk of salinity. Both the high yielding fruit varieties are fast growing and increasingly produced in coastal areas.

The Guava fruits have high calorific values carotin, vitamin C, B1, B2, calcium, phosphorus, iron that can heal different type of diseases. Three years old Guava plant can yield 100–125 kg of fruit. In local market it has good demand for sell and small farmers can earn additional household income after own consumption. BAU Kul is another improved fruit varieties which can yield two to three times in a year. A 1-year old Kul can yield 8–12 ton of fruit per hectare of lands. People consume the variety as substitute of carbohydrate which has important food values for vitamins and minerals. There are multiple food products can be produced from Guava and Kul to increase economic benefits. Small investment is mostly required in collection of grafted seedlings of both the varieties. Under the technical support of Bangladesh Agriculture University, the CBACC-CF project demonstrated BAU Kul and Guava in four coastal districts. As people have traditional knowledge in pit digging, application of organic manure and out planting system and so promotion of the new varieties are easier.

Since the introduction of the varieties, there has been growing interests among community for using and planting around homestead and fallow part of the agricultural lands. Any farmer can adopt the practice where women can contribute for maintenance activities of the fruit garden. This is also possible to cultivate under vegetation along with the fruit varieties which increase short-term income and multiple uses of lands. While high yielding fruit varieties has year round demand, there is lack of people's skill on the quantity of inorganic fertilizers to be applied, as well as remedy measures for reducing risks of diseases and pest attacks. Proper selection of the planting site height above regular inundation or water logging is important to avoid seasonal weather risks and enhance the benefits of the adaptation practice.

14.4 Other Examples of Coastal Adaptation Practices

Local communities have been practicing diverse livelihood practices depending on their needs and capacity to use traditional knowledge and external resource available in coastal areas. Some adaptation practices have been explored from "Reducing Vulnerability to Climate Change (RVCC)" project documents for further understanding and dynamics of livelihood in coastal areas (Ahammad 2010).

14.4.1 Crab Fattening

Crab fattening is increasingly accepted livelihood practices of many families in south-west coastal districts of Satkhira, Bagerhat and Khulna. In the past years, rural women experienced collection of young crab with simple technique and sold in local market for income. Due to saline habitat and the largest mangrove "Sundarbans" close to the region, collection of young crab and nurturing in separate ponds are increasingly preferred for income generation. The initial cost of crab collection is not as much as those farmers can collect young/juvenile crabs from fishermen at low-price. The local sell of young crabs is vital income source for poor fishermen families where alternatively the farmers continue the business for almost a year. There is a less span of time for maturing of the crabs (<28 days) to be suitable for export size.

The livelihood practice can be easily promoted in extended coastal communities due to tidal inundation and water logged saline conditions and locally available feed favors the crab cultivation. There is not much required of additional lands and particular seasonal weather variability as threats to crab fattening. Coastal landless families or marginalized farmers who cannot undergo minimum agricultural cultivation due to salinity in a year they can adopt the practice for regular income. Using community ponds and sharing system there is also opportunity for poor families who have no own ponds for crab fattening. While crab production has local demands, much of its secured benefits are not equally shared by poor people. To optimize the benefits of small scale livelihood practices for adaptation, access to local market and international exports are highly required.

14.4.2 Mele Cultivation and Mat Preparation

Mele is produced locally from a type of reed and traditionally used by coastal families in south-west coastal districts. While raw *mele* is used for animal fodder, the dry *mele* has large demand for producing durable mats. *Mele* mats have local and countrywide market which farmers can use for their livelihoods. As a saline prone areas considering *mele* are grown and practiced within certain limit of tidally influenced brackish and fresh water. *Mele* production can be continued throughout the months of a year and providing minimum income. There is yet environmental risks in *mele* cultivation due to its less salinity tolerance and much requirement of irrigation in cultivation seasons.

14.4.3 Poly Culture

This is a traditional practice for consecutive use of agricultural land in coastal districts Khulna and Satkhira. Farmers use their paddy lands for combined cultivation of paddy, shrimp and fin-fish in different seasons. The practice requires less cost and time initially due to same unit of land which can be used for production. The paddy cultivation begins with monsoon rain when salinity is about to leach out with freshwater inflow around June onwards. At that time, there is a particular system locally people adopting to raise their surrounding lands in a dyke form, or locally called "Gher"/pond to retain fresh water which is simultaneously used for Aman rice and Sweetwater shrimp "Galda". Freshwater reduce the salinity level and restore natural quality of the pond where additional organic matters are enriched in soil and planktons available for food of shrimp. To farmers few white fishes are also naturally grown in the land with paddy and *Galda* shrimp.

The poly culture provides twofold household income at a time as people usually harvest both paddy and shrimp between October and November. Following double harvesting the pond owner also adds income from the remaining fishes. With onset dry season saline water starts growing, and farmers converts the land into salt water shrimp (*Bagda*) in pond and continue up to June. A complete income turnover per year by the land use system can be effective adaptation practice for any farmer irrespective of land size. There is yet local people less capable in managing the traditional practices for crop rotation management and fish culture with respect to fresh and salt water as well as uncertain whether hazards.

14.4.4 Floating Garden

Floating garden is a special kind of traditional livelihood practice which people are adopting over the years in flood-prone southern districts (Pirojpur, Gopalganj). Following monsoon rain or flood events, water logging creates periodical water stress to land based agriculture system when people have no alternative livelihood means. The floating garden provides alternative agriculture practice to people for producing vegetables in the water logged conditions through "Hydroponic" system. The size of each garden (locally called *Baira*) is flexible and it can be around 4–6 ft width, 25–30 ft long and 3–4 ft height. A farmer can easily prepare a bed with own labor and locally available raw materials namely, water hyacinth, rice stub, coconut husk and other plant materials. In the initial phase of preparation, the collected water hyacinth is tied together and overlaid with bamboo. In consecutive turns or days additional water hyacinth is put on bamboos to ensure the thickness of the garden. Once the basic structure of the bed is prepared, the water hyacinth is allowed to rot. In 3–4 weeks of rotten, the top portion of the bed is enriched with primary nutrients (phosphorus, nitrogen and magnesium) which acts as organic manure and make suitable for transplanting of different vegetable seedlings. The naturally grown quality and eco-friendly garden without soil also reduces the application of additional chemical fertilizers for improving crop productions.

The practice mostly replaces the soil based agriculture which is entirely not possible in this period. By adopting the technique, farmers usually produce short-rotation vegetable varieties on the floating garden which are important for household foods, nutrition and alternative income generation. Not less than 31 different vegetable varieties can be cultivated in the garden depending on water depth and duration in monsoon and winter seasons. Of the vegetables, there are spinach, beans, cabbage, cucumber, eggplants etc. which becomes harvestable within 20–25 days of the transplanting. The significant note of the practice is three to four times high yielding capacity of vegetables around a year than soil based production system.

To some extent the practice is observed in water logged lands and adjacent homestead areas. Farmers who are entirely dependent on agriculture, receiving double benefits by using the organic residual of the garden even after water recedes for winter vegetation in farming lands. To adapt to frequent and intense floods and water logging areas, floating garden practice is increasingly found as an alternative and easily replicable land use technique for household income generation in Bangladesh. With the external support and improved knowledge the practice can be strengthened with sustainable benefits as asset to adaptation of seasonally vulnerable people.

14.4.5 Cage Culture

The practice has been introduced in inundated and water logged areas for fish production. With submergence of agricultural lands and seasonal wetland, the cage system has been effective, alternative and small scale income generation source for farmers and single family. The cage is rectangular or square shaped and prepared with net that can be submerged in 2–3 m water. The cage can be locally purchased with nominal cost and no additional materials. The fast growing fish larvae or finger lings with food is put inside the cage where it can grow up in natural aquatic habitat. This is possible for a family to harvest matured fish for household consumption as well as market sell in 8–12 weeks. The production and benefits by cage culture can be increased depending on the numbers of cages are practiced in private and public common lands.

The significant advantage of the culture is to adjust with tidal inundation and water logged risks in coastal and flood prone areas of Bangladesh. Without agriculture farming opportunities, there would otherwise be no functional livelihoods of majority people in this period. The minimum livelihood activities can be secured by the practice as regular income to marginalized farmer families. The practice neither requires additional knowledge and cost, nor much labor and so women can also adopt the practice easily. There are no environmental risks in the practice and lack of viral infestation in the fish culture. People can multiply the economic benefits of the system by investing income in consecutive agricultural farming as a part of short to mid-term adaptation practices. The adaptation practices is significant response to growing water related climatic stress where promotional trainings and access of marginalized and landless people to submerge and community based wetland management in particular seasons must be secured.

14.5 Coastal Livelihood Adaptation: What Is Needed

Coastal people are increasingly adopting diverse livelihoods for adaptation which are related to local climatic risks and seasonal variability as well as availability of the resources for them to access and generate benefits immediately. Some of the livelihoods are traditionally preferred at household level for regular or additional income generation. A few other livelihood practices are also found as community resources for group based income generation. The most striking issues of livelihood for adaptation is whether these practices secure income, what extent these are capable for seasonal risk management (e.g., tidal inundation, water logging, salinity increase etc.) and how local and external support mediate resource ownership for suitable benefit distribution. Coastal communities are often forced by socio-economic changes at large scale process which shapes their linkage to institutions (norms and rules) and organizations at other scales (Craig and Ruhl 2010). Drawing current evidences of changing coastal livelihoods from field experience are important for understanding, developing knowledge on existing risks to promote adaptation measures.

Different degree of seasonal and periodical threats as well as change in temperature and precipitation are important in coastal livelihoods to understand adaptation. The external climate stimuli are pressing traditional practices beyond agricultural practices; rather than people are improving the techniques with own knowledge and innovation as well as supports of govt. and NGOs. The traditional agriculture and fishing practice is changing in different scale of management capacity, from individual response to community actions. Landless and marginalized farmers who have no options for agriculture farming or fish culture due to water logging or saline ponds, the Triple F arrangement of ditch system secures their household protein sources and periodical income. By protecting the ditch there is possible duck rearing which can generate fish food and additional household protein sources.

People perceive the changing seasonal threats from their experience and adopt new information, innovative techniques and skills to blend with traditional practices. Changing cropping practices with respect to seasonal risks are currently envisaged for introducing new rice varieties to withstand higher salinity and temperatures in coastal areas (Ali 1999). Farmers are not entirely depending on agriculture, or fishermen on pond culture and open fishing. In several cases, people are emphasizing on small scale agriculture by changing cropping cultivation pattern; mixed cultivation with agriculture and fish cum duck rearing. Much of the traditional practices can only secure household foods and limited incomes where it has been noted of changing land uses to enhance livelihood income resilience. Traditional practices cannot be referred to sustainable as these are often isolated and characterized by weak financial inputs (internal/external) and protective infrastructure (Mallick et al. 2011) for continuing the benefits in extended seasons. The CBACC-CF project incorporates traditional knowledge of local community for seasonal risk reduction through improved cropping pattern with innovative dyke system which has been found to increasing annual production and income beyond regular incomes.

The significant point of coastal livelihood in current paradigm is sustainability of practice and actions. Among the documented adaptation experiences except the Triple F, many of the household livelihood practices are only managing seasonal risks to some extents which are neither sustainable nor increasing income to adapt to subsequent shocks around a year. Depending on only current practices, small landholders and poor disadvantaged groups can maintain coping strategies through taking loan, selling labors or leasing lands (Parvin et al. 2008; Pouliotte et al. 2006), but integration of livelihoods pattern are important for adaptation at individual and community level. The Triple F model of CBACC-CF project provides integrated livelihood measures over seasonal risks to multiple year targeted resource management (Nandy 2011, 2012). The practice is innovative in type, at the same time supplementary to traditional agricultural cultivation or fish culture for income source of coastal people. For instance, the involved community applied their traditional knowledge for hanging vegetables in scaffolding system on dyke. Freshwater has been irrigated by themselves for shrimp farming apart from project inputs to increase income in extended seasons. It has been observed from the project experience that community based resource management can provide better identification of the risks, shared learning and strengthening household income not on seasonal basis as well as annual.

Strengthening adaptation capacity requires blending individual skills and household capacity with external institutional supports for technological acceptance. The dynamic geo-morphological nature and disaster surprises in coastal areas often override the knowledge of local people and use of available resources to reduce the problems in the long-run. Livelihood expresses the capacity of marginalized vulnerable groups to cope with climatic shocks and access to resources and technology. This has been possible to blend individual experiences in continuous livelihood development in the NAPA project. Some of the households who have very other limited livelihoods (farmers or landless) find the Triple F practices as additional and only resource generating sources. The significant part of the resource access and sharing is land ownership arrangement and external support for incorporating climatic risks in building particular ditch and dyke system.

Evidently land is important resource for adaptation, and important for coastal people how to rearrange and engage its multiple uses in resource management by reducing the seasonal risks. Drawing experience of the NAPA project, institutional support for land access and knowledge transfer of improved crop varieties through training and awareness building can strengthen land use capacity and reinvigorate livelihood approach. The statement is important for any adaptation practice promoted by other organizations to incorporate cost-effective values of new interventions how community accepts and sustain the benefits in the long-term adaptation. To note that institutional interventions for coastal land acquirement and sharing among local community must be carefully followed to ensure adaptation benefits in the long-run.

Community can sustain livelihood benefits in changing climatic risks by ensuring their access to local resource ownership. Depending on current resource capacity, people have different level of understanding and needs for managing new innovation practices. While transferring innovation practice at the local level very often pro-poor resource distribution and selection of the right innovation is important, and remain challenges. For instance, landless and marginalized farmers largely accepted the ditch and dyke arrangement as significant resource than any other group of people. Despite the fact, empowering particular vulnerable coastal people through land ownership distribution in the CBACC-CF project remains critical task. This is not for differentiated vulnerability and capacity of economically land owners that they can manage risks; the group also receives the major advantages due to their access to local institutions. Access to new innovation opportunity and optimize benefits is interrelated with user interface between community and institutions. Some other adaptation practices (crab fattening, poly culture, floating garden etc.) require initial investment cost and labor, access to land, improved technology, skills and market. All these associated factors are socially and institutionally driven and often mediating the individual capacity whether the practice can be empowering the vulnerable groups.

Adaptation practice is mostly interlocked within institutional response for promotional activities to managing observed risks in Bangladesh and less focusing on integrating other social constructions at community level. Making long term decisions for coastal adaptation now involves consideration of both the climate change uncertainties and complexities and levels of stakeholder support (Tompkins et al. 2008). The NAPA project focused on institutional strengthening through capacity building training of local government officials for improving collaboration and livelihood input delivery. Major activities of the project are attempted to be integrated within the capacity and roles of four departments of Forest, Agriculture, Fisheries and Livestock. These departments have opportunity to share and transfer knowledge and resources to community and local stakeholders for integrated livelihood management. Since the project, the collaboration of these departments is increasing within formal structure and mostly not adequate at the community level. These institutions identified their key adaptation roles though these are not empowered in policy influence and local resource ownership. National land use policy is inadequate to define local institutional capacity with particular focus on coastal areas and develop integrated resource management.

Institutional networking across horizontal and vertical level is important for design and promotion of cost-effective adaptation interventions. In livelihood adaptation project, national institutions must consider changes in relevant policy to open up existing local institutional interface for strengthening support to implementing parties among them and from external departments of same level. Coastal livelihoods are not only related to responsibility of few departments rather than roles of other local stakeholders who are involved in disaster risk management (Rawlani and Sovacool 2011). Protective infrastructure like coastal embankment and effective drainage maintenance can reduce seasonal water logging risks to agriculture cultivation. The major institutional roles of CBACC-CF project has only four departments until recently which often excludes the responses of those other government local institutions involved in water management. While the project initiates local institutional interface for adaptation, the evolving experience may be extended to integrate the support of other departments to reduce overriding resource management problems in coastal areas and eventually adaption costs.

14.6 Conclusions

Coastal livelihoods require modification of traditional land use and integrating practices with respect to risks and people's access to adopt and continue in sustainable manner. Compared to isolated adaptation interventions, the CBACC-CF project innovation created multiple opportunities through livelihood ownership as well as long-term resource generation. Ownership development has been important approach in the Triple F model which opens up particularly integrated livelihood practice for adaptation with the collaboration of local community which is also important for social empowerment of landless and marginalized households. Diversification contributes to household adaptation in Mozambique due to flexible livelihood options though inequality in access to resource and markets impeded resilience among the community. The dual land use system is recognized by local communities as pro-active livelihoods to drought risk management, but household size and labor intensity have characterized the benefits for particular social groups to participate in the coping strategies (Osbahr et al. 2008). The Triple F model can manifold livelihood benefits in the long-time scale upon ensuring effective coastal zone policy and responsive delivery institutions for implementation at the local level.

Livelihoods are embedded within integrated social-ecological functioning that enhances adaptive capacity of the system. The livelihood strategies correspond to different household needs in stress and post-shocking period to fulfill the adaptation gaps. People used extensification, intensification, diversification and migration strategies for coping with periodical stress in Morogoroof Tanzania (Paavola 2008). However, the adaptation strategies of Tanzania has also problems in effective governance of environmental resources; promotion of market participation to stimulate both agricultural intensification and diversification of livelihoods; and building human capital. Coastal people are increasingly adopting diverse livelihood practices at household level in Bangladesh. The livelihood strategies have few weakness which are focusing only seasonal climatic risks without incorporating long-term climate dynamics, social and ecological changes. Use of advanced climatic information, irrigation and salinity management, and integration of single livelihood to multi-level resource generation required within existing adaptation practices of households. Contrary to the point, the Triple F model has substantially focused on integration and protection of livelihoods through capacity building of community and households equally. Adaptive capacity is interconnected at different scales and depending on degree of response from both individual and community as well (Smit and Wandel 2006). The spontaneous interaction of community and individual has advantages in livelihood adaptation for raising voice in service claim and access to potential political and economic institutions.

The adaptation innovations relate to the emerging threats of livelihoods in changing climate and institutional capacity to progressively responding through appropriate technology to the demand (Rodima-Taylor et al. 2008). Social acceptance of innovation, livelihood patterns and strategies shows a great potential for analyzing climate action in the complex and multi-scale actor environments. Most adaptation measures need to be cost-effective for institutional deploy around community level as well as within much of their capacity to accept and promote at individual context. Community invested their time and labor in developing the ditch and dyke system for diverse resource generation in the Triple F model. In spite of that, the land use innovation practice cannot be said fully cost-effective until initial institutional support to local people is providing additional financial and technical benefits of particular marginalized social groups for their regular livelihood activities. This is equally important consideration in introducing other practices including crab fattening, floating garden and poly culture whether marginalized farmers can invest finances and technology, and then develop capacity to optimize the successive benefits. DaCosta and Turner (2007) emphasis on sustainability of the new practices for sampan dwellers is a matter of fact in Vietnam due to financial and natural risks in the flood prone areas as well as water contamination in the raising aquaculture ponds. The resettlement arrangement of sampan dwellers provides insufficient lands and aquaculture system only considers current income generation. Building financial capital through the aquaculture ponds would take long-time to ensure their future adaptation capacity.

Attention to social actors with their diverse interests, perceptions and purposes helps to contextualize the notions of community and participation. Local networks and associations, and the relationships and patterns of reciprocity and exchange, are therefore paramount to building adaptive capacity. The community based livelihood approach can transfer knowledge and best practices and improve risk management capacity at individual context as well. Edwards and Wiseman (2011) emphasize on community adaptation through proactive, intentionally transformative capacity to address the future shocks. The ditch and dyke approach was based on community level decision making which alternatively improves individual capacity to share and learn from others for transferring knowledge in seasonal crop diversity, application of organic manure as well as fresh water irrigation to enhance future livelihood benefits. Drawing the Triple F experience, any innovation practice may be assessed at the community level for efficiency and acceptability while also disseminating individual best practices as part of knowledge for others.

A significant institutional barrier exists in clarifying authority and improving coordination, or insufficient public involvement and deliberative processes for legitimate and accountable coastal resource management (Lebel 2012). Existing social and economic level of individual families and their access to institutions and market remain important determinants with innovation practices. The effective claim-making on local resources as well as policy support from public institutions are essential part of adaptation strategies for enhancing the climate resilience of the poor. There are often lack of coastal policy review, local institutional monitoring and vested resource interests of particular groups also underscoring livelihood risks of marginalized stakeholders at different levels. Local community experiences in project implementation and effective actions demonstrate relevant basis for systemic policy changes at a national level (Sieghart and Ganapin 2011) and also fosters partnership with govt. agencies, powerful resource users and other stakeholders.

Large-scale actions strengthen local governance and community groups responsible for managing coastal resources, improvements in coastal infrastructure, and migration to non-coastal areas (Cinner et al. 2012). Medium-term investments in institutional capacity building (i.e., financial planning and management, knowledge and information sharing) and cross-scale linkages will likely be critical to facilitating the success of these emerging institutions. Collaborative Triple F arrangement demonstrates potential inter- and intra-institutional integration and better understanding for climatic risk reduction responses through productive and protective coastal land management with local communities. Informal institutional collaboration has been strengthened among government agencies to the extent for implementing and monitoring of the livelihood system in coastal areas. The new form of institutional adaptation interface exists in only early stage and so inadequately equipped with the required policy changes for sustainable livelihood management in coastal areas. The short-term experience of the project must be opened up for sharing with and/or involving many other influential social and political stakeholders who may have divergent roles in policy making and local resource management process and proliferate the adaptation initiative.

References

Adger NW, Hughes TP, Folke C, Carpenter SR, Rockstrom J (2005) Social-ecological resilience to coastal disasters. Science 309:1036–1939

Agrawala S, Ota T, Ahmed AU, Smith J, van Aalst M (2003) Development and climate change in Bangladesh: focus on coastal flooding and the Sundarbans. OECD Publications, p 70

Ahammad AU (ed) (2010) Reducing vulnerability to climate change: the pioneering example of community based adaptation in Bangladesh. Centre for Global Change (CGC) and CARE Bangladesh, Dhaka, p 156

Ali A (1996) Vulnerability of Bangladesh to climate change and sea level rise through tropical cyclones and storm surges. Water Air Soil Pollut 92:171–179

Ali A (1999) Climate change impacts and adaptation assessment in Bangladesh. Climate Res 12:109–116

CBACC-CF (Community Based Adaptation to Climate Change through Coastal Afforestation) (2012) Training module on rice production technology. CBACC-CF Project, Department of Agriculture Extension Component, Khamarbari, Dhaka, p 24

Cinner JE, McClanahan TR, Graham NAJ, Daw TM, Maina J, Stead SM, Wamukota A, Brown K, Bodin O (2012) Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. Glob Environ Change 22(1):12–20

Craig RK, Ruhl JB (2010) Governing for sustainable coasts: complexity, climate change, and coastal ecosystem protection. Sustainability 2:1361–1388

DaCosta E, Turner S (2007) Negotiating changing livelihoods: the sampan dwellers of Tam Giang Lagoon, Viet Nam. Geoforum 38:190–206

Edwards T, Wiseman J (2011) Climate change, resilience and transformation: challenges and opportunities for local communities. In: Weissbecker I (ed) Climate change and human well-being. International and Cultural Psychology, Springer Science, Business Media, LLC, New York, pp 185–200

FAO (2010) Global forest resources assessment: country report Bangladesh, p 61
Hossain AM, Reza MI, Rahman S, Kayes I (2012) Climate change and its impacts on the livelihoods of the vulnerable people in the southwestern coastal zone in Bangladesh. In: Filho WL (ed) Climate change and the sustainable use of water resources. Springer, Berlin, pp 237–259
Lebel L (2012) Governance and coastal boundaries in the tropics. Curr Opin Environ Sustain 4:243–251
Mallick B, Rahman KR, Vogt J (2011) Coastal livelihood and physical infrastructure in Bangladesh after cyclone Aila. Mitig Adapt Strateg Glob Change 16:629–648
MES (Meghna Estuary Study) (2001) Hydromorphological dynamics of the Meghna estuary. Meghna Estuary Study (MES) project, Bangladesh Water Development Board, Dhaka. In: Ahmed A (ed) Some of the major environmental problems relating to land use changes in the coastal areas of Bangladesh: A review, Journal of Geography and Regional Planning 4(1): 1–8
Moniruzzaman M (2012) Impact of climate change in Bangladesh: water logging at south-west coast. In: Filho WL (ed) Climate change and the sustainable use of water resources, climate change management. Springer, Berlin, pp 317–336
Nandy P (2011) Forest, fish and fruit: new model of climate change adaptation in Bangladesh. In: Abstract, 5th international conference on community based adaptation to climate change, Dhaka, p 188
Nandy P (2012) Community based adaptation through the application of FFF model—a mound-ditch model to adapt to climate risks. http://www.asiapacificadapt.net/adaptationforum2012/sites/default/files/Paramesh%20Nandy_BANGKOK-Adapt-Forum-2011%20%5BCompatibility%20Mode%5D.pdf. Accessed 12 Dec 2012
Nandy P, Ahammad R (2012) Navigating mangrove resilience through the ecosystem based adaptation: lessons from Bangladesh. In: Macintosh DJ, Mahindapala R, Markopoulos M (eds) Sharing lessons on mangrove restoration. Mangroves for the Future and Gland/IUCN, Bangkok, Thailand/Switzerland, pp 243–254
Nandy P, Paul SP, Moula MG, Imam MF, Basak SR, Miah MAQ, Mannan MA (2003) Stakeholder analysis through participatory rural appraisal for land use and joint forest management in raised coastal areas. PRA Bulletin. Plantation Trial Unit Division, Bangladesh Forest Research Institute, p 58
Nandy P, Islam MA (2010) Climate resilient coastal zone development in Bangladesh: participatory governance for common resources management. In: Ramanathan AI, Bhattcharya P, Dittmar T, Prashad MBK, Neupane BR (eds) Management and sustainable development of coastal zone environments. Capital Publishing Company, New Delhi, pp 58–72
Nicholls RJ, Wong PP, Burkett VR, Codignotto JO, Hay JE, McLean RF, Ragoonaden S, Woodroffe CD (2007) Coastal systems and low-lying areas. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, pp 315–356
Osbahr H, Twyman C, Adger WN, Thomas DSG (2008) Effective livelihood adaptation to climate change disturbance: scale dimensions of practice in Mozambique. Geoforum 39(6):1951–1964
Paavola J (2008) Livelihoods, vulnerability and adaptation to climate change in the Morogoro region, Tanzania. Environ Sci Policy 11(7):642–654
Parvin GA, Takahashi F, Shaw R (2008) Coastal hazards and community-coping methods in Bangladesh. J Coast Conserv 12:181–193
Pouliotte J, Islam N, Smit B, Islam S (2006) Livelihoods in rural Bangladesh. Tiempo 59(April Issue):18–22
Rahman MH, Lund T, Bryceson I (2011) Salinity impacts on agro-biodiversity in three coastal, rural villages of Bangladesh. Ocean Coast Manag 54:455–468
Rawlani KA, Sovacool KB (2011) Building responsiveness to climate change through community based adaptation in Bangladesh. Mitig Adapt Strateg Glob Change 16:845–863
Rodima-Taylor D, Olwig MF, Chhetri N (2008) Adaptation as innovation, innovation as adaptation: an institutional approach to climate change. Appl Geogr 33:107–111

Shaw R, Krishnamurthy R (2012) Coast and communities: the Linkages. In: Shaw R, Tran P (eds) Environment disaster linkages. Community, environment and disaster risk management, vol 9. Emerald Group Publishing Limited, Bingly, pp 101–112

Sieghart LC, Ganapin D (2011) Pace of change: climate change and the empowerment of local communities. In: Filho WL (ed) The economic, social and political elements of climate change, climate change management. Springer, Berlin, pp 837–845

Smit B, Wandel J (2006) Adaptation, adaptive capacity and vulnerability. Glob Environ Change 16:282–292

Tompkins EL, Brown K, Few R (2008) Scenario-based stakeholder engagement: incorporating stakeholders preferences into coastal planning for climate change. J Environ Manag 88: 1580–1592

Chapter 15
Coastal Ecosystem Based Adaptation: Bangladesh Experience

Paramesh Nandy, Ronju Ahammad, Mesbahul Alam, and Aminul Islam

Abstract Bangladesh is confronting multitude threats of climate change related extreme events. The decadal observation provides strong evidences of climate changes in terms of excessive or minimum rainfall events, changing frequency and intensity of floods, cyclone and tidal surge, and sea level rise have been gradually increasing fast and slow impacts. The cyclonic wind and tidal surges along coasts; or floods and river erosion in floodplain areas already incurred severe degradation and loss of the associated ecosystem services. Coastal ecosystems are dynamic and possessing different resources including accreted lands, mangroves, estuaries, rivers and seas which are contributing to a range of productive and protective functions in Bangladesh. By contrast, extreme events and climate changes are increasing impacts persistently on coastal resources at different degree and scale through disaster that causes severe damages of protective mangroves; salinity intrusion and tidal inundation height degrades regenerative functions and land use productivity. Mostly coastal resources are highly sensitive to climate changes that results significant loss of traditional land uses for agriculture or fishing, and eventually weaken the capacity of the protective ecosystem and community for adaptation. Protection of coastal livelihoods through physical embankment or mangrove afforestation for land stabilization was already recognized to be effective measure in Bangladesh without

P. Nandy (✉)
CBACC-Coastal Afforestation Project of UNDP-Bangladesh, Dhaka, Bangladesh
e-mail: pm.cbacc@gmail.com

R. Ahammad
Community Based Adaptation to Climate Change Through Coastal Afforestation Project, UNDP, Dhaka, Bangladesh

M. Alam
Ministry of Disaster Management and Relief, Government of Bangladesh, Dhaka, Bangladesh

A. Islam
United Nations Development Programme, Dhaka, Bangladesh

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*, Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_15, © Springer Japan 2013

understanding sustainability and dynamic capacity of these interventions for adaptation of local communities. Adaptation in coastal areas is increasingly becoming complicated and difficult to isolate any of the social and ecological activities which required integrated resource management and land use planning for long-term adaptation. There are needed understanding protective and productive uses of coastal lands for integrating ecosystem into adaptation and sustaining community benefits. The paper presents potential roles of coastal land uses for ecosystem based adaptation in Bangladesh. The paper addresses some emerging adaptation and resilience perspective in coastal ecosystems followed by sharing experience of an innovative land use pattern, and discussed the diversified benefits of conservation, livelihood sustainability, community integration and institutions for ecosystem based adaptation. The potential role of ecosystem based adaptation is integrated and protective resource management approach through transformative land use system, building community ownership and resiliency of coastal forests. Decentralized roles of community and local institutions in participatory decision-making of land uses and climatic risk management offers flexibility and renewal opportunities and enhance sustainability of protective coastal ecosystems. Community based resource governance not only ensures ecosystem based adaptation locally, but also contributes to managing dynamic social–ecological system in coastal areas as well as global mitigation.

Keywords Climate change adaptation • Coastal ecosystems • Land use • Resilience • Transformation

15.1 Introduction

Climate change induced shocks are largely shaping coastal ecosystems into extremely vulnerable states (Klein et al. 2000). Climate related shocks and extreme events increase vulnerability of low-lying coastal regions including deltaic plain and Small Island countries (Nicholls et al. 2007). Bangladesh, one of the great deltas in the world possesses a 710 km long and exposed coastline. Coastal ecosystems represent opportunists' roles to local and national economic growth in Bangladesh though morphological shifting of coastal boundary and extreme events has threatened social and ecological functions in spatial and temporal scale (Nandy 2010). Drawing inter govermental Panel on Climate Change (IPCC) evidences of climatic risks in coastal ecosystems Bangladesh has much relation to increased sea surface temperature; change in storm frequency, intensity and track; altered wave and water runoff; and sea level rise (Nicholls et al. 2007). These changes will have consequent effects on ecosystems and eventually affect socio-economic systems in the coastal zone. While majority of coastal population possess highly climate sensitive livelihoods in Bangladesh, particular poor and marginalized groups are losing adaptation capacity to manage current and long-term shocks and uncertainty due to inadequate access to natural, financial and institutional assets.

Coastal ecosystems provide a range of ecosystem services which are important for adaptation and building resilience (Adger et al. 2005a, b). Unsustainable use and unrestricted development of land and resources for maximizing the financial benefits results not only in the depletion of the resource stock or flow provided, but also in the inability of other functions to perform to their full potential such as protection against the sea, habitat for many species and food for many people (Klein et al. 1998). Different studies referred to community-led local resource protection can draw participatory collective actions (Allen 2006; van Aalst et al. 2008) and conserve valuable ecosystem services for livelihood risk reduction and long-term poverty alleviation (Christoplos et al. 2009) to deal with climate change impacts and build resilience of socially disadvantaged communities. But, potential uses of coastal resources and adopting sustainable livelihood practices for vulnerable social groups remain great challenges in prior to adaptation in Bangladesh. Many literatures referred fragmented resource management in coastal ecosystems focused on structural protection (Agrawala et al. 2003; Hossain et al. 2012) and ignored social construction and ownership pattern in local resource governance (Nandy and Islam 2010) which decrease adaptation capacity of marginalized community in Bangladesh.

Participatory resource management can improve environmental integrity, economic efficiency of actions and equity for local community in sustainable benefit distribution (Nandy and Islam 2010). Ecosystem Based Adaptation (EBA) is an emerging integrated ecosystem approach to protect and manage natural resources for producing sustainable goods and services (Vignola et al. 2009; Sterrett 2011). The approach addresses restoration of critical ecosystem services through integrated resource management with multi-dimensional social and ecological opportunities of coastal communities. The significant role of EBA is to involve diverse stakeholders to reduce climatic risks and underlying threats on ecosystem services for enhancing resilience and adaptation in dynamic ecosystem. The paper refers the "Community Based Adaptation to Climate Change through Coastal Afforestation (CBACC-CF) project" as a case study to present its innovative land use and adaption practices to discuss the role of EBA in coastal areas of Bangladesh.

15.2 Adaptation to Resilience: The Need for Transformational Change

Coastal ecosystems are highly dynamic interface of sensitive ecological and social processes between land and sea across the globe (Klein et al. 2003). Adaptation in coastal ecosystems is much complicated due to interrelated diverse ecological and social functions rapidly evolving with morphological changes (erosion and accretion) and human interventions in different scales (van den Bergh and Nijkamp 1998; Klein et al. 2000). Adaptation can be explained for ecological and social aspects in coastal ecosystems to how particular attributes of these systems are vulnerable and adapting to current and future shocks (Klein et al. 1998; Adger 2006). Ecological perspective of coastal adaptation is how and what capacity of species is available for responding and functioning to certain (sediment flow) and sudden (wind and water wave) external changes. Ecological adaptation has further connotation not only to adjustment, but also reorganization capacity and multi-equilibrium domains of ecosystems which is related to resilience (Berkes and Folke 1998). Post-disaster recovery and regenerative functions of mangrove species are important aspects of ecosystem adaptive capacity (Ingram et al. 2006).

Socially viewed coastal adaptation determines communities' ability to adjust with observed coastal changes; climate related stress and projected uncertainty like sea level rise (Fussel 2007). Adjustment to current shocks and looking forward to adapt to future risks is important for understanding of adaptation in social systems. Adger et al. (2009) stresses on scales and actors are important for understanding appropriate adaptation. Coastal communities have cultural legacy to adapt in the past years with own understanding of cyclonic risks, timely migration to safe shelter and avoiding loss of property in Bangladesh. Community accepts new adaptation inputs or technologies as adaptation measures which may fit to particular social settings or otherwise increase vulnerability. Indeed, access of coastal communities to livelihood resources (natural, economic, institutional, human and social) determines the degree of vulnerability and space for social adaptation. A range of stakeholders including public, private businessmen, and decision-makers are engaged and mediating these resources at local, national and regional scales that adaptation of coastal communities are embedded within those social and institutional actions (Nandy et al. 2003).

The high exposure and sensitivity of coastal communities to climatic shocks expresses their more vulnerability (Cinner et al. 2012) and fewer options for adaptation. Cutter points to vulnerability as a context specific stress that coastal community face certain degree of disasters and possess level of adaptation capacity (Cutter et al. 2008). Access to social support systems, technology, protective infrastructure and assets are pivotal factors enhancing adaptive capacity in developed countries. By contrast neither of these supports and access to coastal societies are equal cases in developing and least developed countries and particular marginalized coastal communities. For example, Bangladesh and The Netherlands share a similar physical susceptibility to sea-level rise threats. But, Bangladesh lacks economic resources, technology, and infrastructure where the Netherlands can call on to respond to the potential impacts. However, having adaptive capacity is no guarantee that it is used successfully. In this respect, the development and use of new and existing scientific information to address the gaps in adaptation measures are especially important.

Adaptation process involves multilevel governance from international policy to national strategy development and implementation at local level. Adger (2003) emphasizes on social capital through building networking and trust among government, civil societies and community groups substitute responsibilities to take adaptation actions in collective manners. In several literatures local level has gained valuable currency for appropriate ground of adaptation measures (Wilbanks and Kates 1999; Naess et al. 2005; Agrawal et al. 2008). There has reasonable acceptance for vulnerability as a localized phenomenon and adaptation interventions affect relatively community. Communities perceive the most underlying root causes of vulnerability on livelihoods and can address their current capacities available to cope and deliver information needed for taking adaption actions (van Aalst et al. 2008). Adaptation design developed from bottom is socially acceptable and cost-effective practices for communities to adjust with vulnerable situation (Adger 2003). Community based adaptation (CBA) is increasingly drawing attention in many of non-gov. and govt. department programmmes to identify local disaster risk and climate related problems and find solutions locally. CBA has been a practical approach of Community Based Disaster Preparedness (van Aalst et al. 2008), Community Risk Mapping (Reid et al. 2009) and adaptive strategies for coastal community through resource mobilization, using social capital and access to formal and informal networks for receiving information and skills to anticipatory adaptation (Ensor and Berger 2009).

Adaptation response satisfies certain purposes of social and ecological systems (Adger 2003). Individual behavior and institutional interplay with society determine the mode of adaptation whether it should be autonomous or planned. Adaptation literatures recognized communities adapt to social and environmental stress autonomously with their resources and knowledge to survive without external inputs (Tompkins and Adger 2004; Fussel 2007). Planned adaptation is related to anticipation of climate related risks for pre-arranged measures. Coastal adaptation responses have long-time followed three practical techniques for: protection; accommodation and retreat. Protection response provides protective structures of natural resources followed by building hard or engineering structures like sea wall (dike in Dutch/earth embankment in Bangladesh) for protecting land from sea and continuing land uses and functionalizing different services from coral reefs, agriculture, freshwater and forest products Accommodation is about the continuous adjustment practices through beach nourishment; elevating the house plinth; cultivating fast growing and salt tolerant crops. Retreat undergoes abandonment of any undesirable coastal areas without further interventions.

A set of adaptation responses without integrated understanding ecological and social process address coastal vulnerability in narrow ways. The early interventions of adaptation technologies are protection oriented which have considered for managing sea level rise and flooding risks. Much in adaptation for monitoring and evaluation feedback (Nicholls and Branson 1998), learning and innovation are not equally accepted in coastal development process. Shoreline management and reclamation of coastal lands have attenuated for agricultural and industrial settlement in Netherlands. The response is alternatively shaping coastal natural system into disequilibrium state that is likely to be collapsed with changed sediment flow and lack of additional measures. Building dyke (coastal embankment) is hard adaptation measure for reducing impacts of storm surges in coastal areas of Bangladesh. Neither of the dykes was designed taking account of climatic scenarios in particular of storm surge frequency and height and inundation regime and created trade-offs like water logging with inundation and salinity intrusion inside of the embankment.

Our understanding of coastal ecosystems is less developed and limits to effective adaptation plan due to its large scale and process. The significant constraint of coastal management is to define how different constituents in the complex system respond to climate changes and adaptation measure (Nicholls et al. 2007). Adaptation practice is likely to face surprises of climate related disasters and needed for nursing of present actions and innovating from past learning towards resilience coastal ecosystems (Tschakert and Dietrich 2010). Social and ecological processes of coastal ecosystems are closely interactive that adaptive strategies must be analyzed within an integrated resilience framework than isolated development interventions (Klein et al. 1998). Coastal adaptation needs to look broader scale of resilience lens for simultaneous evolving of social and ecological capacity. Enhancing resilience is appropriate for adaptive measures in integrated social–ecological system.

15.2.1 Coastal Ecosystem Resilience

Resilience is the capacity of social and ecological system to absorb climate related shocks, continue function and reorganize (Walker et al. 2004). The resiliency approach builds partly the capacity of coastal ecosystems as integrated and complex system to persist with perturbations (catastrophic events and human activities) without diminishing critical and diverse functions which is either needed for sustaining ecological process and delivering resources to social well-being or both. Resilience perspective promotes shifting policy towards more flexible and adaptive management of coastal ecosystems. There are reasons that frequency of hazards is increasing and turning into disasters and decreasing the resilience of the coastal ecosystems. There are much adaptive strategies required to retain ecosystem functions with coastal morphological changes and climatic and societal dynamics (Adger et al. 2005a, b). Managing resilience is likely to enhance adaptation capacity to disaster surprises and climate related uncertainty beyond current predictions and management interventions (Berkes and Folke 1998; Berkes et al. 2003; Walker et al. 2004).

Ecological resilience relates to understanding the role of biodiversity, functional and response diversity of species and habitat connectivity in changing climatic and human induced stress. Diversity of species is vital for absorbing shocks and regenerating from and aftershocks of tsunami, cyclonic shocks and slow onset disasters in coral reefs or mangrove ecosystem. Some of the species are likely to be redundant during coastal ecosystem development though these provide post-disaster habitat connectivity for regenerative ecosystem functions of mangrove species (Islam and Nandy 2001). Nandy et al. (2004) noted that source of regeneration, quality seed and species diversity has been crucial to improve ecosystem function of mangrove plantation regime in Bangladesh. Mangrove afforestation led by pioneer species Keora (*Sonneratia apetala*) is affected with disease infestation and wind and storm shocks which reduces functional capacity of mangrove ecosystem in Bangladesh (Nandy 2003). Introducing ten commercially productive mangrove species for differently inundated coastal habitats are experimented for second rotation and under-planting with *S. apetala* to improve diversity in plantation forest as well as after careful consideration in natural mangroves of Bangladesh (Islam and Nandy 2001).

Distribution of functional groups and response diversity offers renewal and reorganization of the ecosystems within and across the connected coastal ecosystems. The adaptive response of coastal ecosystem to climate change has key resilience attributes that: focus on buffer capacity than attention on traditional recovery rate (e.g., mangrove succession pattern after disaster, or in deforested lands for shrimp farm or salt pan in tropical countries); shifting regime from single to multiple domain of attractions for overfishing cause collapse of fisheries or coral reef into undesirable states. The single domain management of coastal ecosystem is restraining our perceptions and adaptation boundary to current climate changes. Technological interventions already lapsed to interconnect the ecological process with future morphological changes and climate related events. Resilience provides opportunities to coastal adaptation for simultaneous change and development with optimal management interventions.

Adger (2000) defined social resilience as the ability of human communities to withstand external shocks to their social infrastructure, such as environmental variability or social, economic and political upheaval. Social resilience, including institutions for collective action, robust governance systems, and a diversity of livelihood choices are important assets for buffering the effects of extreme natural hazards and promoting reorganization. Coastal communities that harboring knowledgeable, prepared, and responsive institutions are more likely to be able to prevent the tsunami from making the transition from extreme natural hazard to longer-term social disaster. For instance, fishing communities on Simeulue Island, west of Sumatra and close to the epicenter of the earthquake causing the tsunami, and on Surin Island, Thailand, survived the tsunami thanks to inherited local knowledge of tsunamis and to institutional preparedness for disasters.

The early resilience perspective emerged from a stream of ecology that addressed system dynamics, in particular ecosystem dynamics, and where human actions became a central part of understanding the capacity of ecosystems to generate natural resources and ecosystem services (Folke 2006). The early inclusion of humans as agents of ecosystem change distinguished this ecosystem oriented branch of ecology from the main stream ecology profession. The main stream excluded humans or treated human actions as external to the system and consequently the interdependencies and feedbacks between ecosystem development and social dynamics, and their cross scale interactions, were not on the table. Coastal adaptation is largely focusing on social system without addressing trivial ecological functions. Resilience thinking guides coastal adaptation to respond beyond social domain to more cross-scale interactions in linked social–ecological system (Folke et al. 2005). The variables and processes that structure coastal ecosystem dynamics and sources of social and ecological resilience have to be understood and actively managed to adapt to and deal with the interplay of gradual and abrupt change.

15.2.2 The Transformational Change in Coastal Ecosystem

Coastal ecosystems are influenced by dynamic biophysical and social factors which require understanding factors triggering for desirable transformation. Global climate change shapes rapid transformation in coastal ecosystems due to dynamic and functioning complexities. Climate change creates large scale uncertainty where transformability is important towards improved social–ecological system (Folke 2006) beyond current adaptation management. Coastal transformability is the capacity of social and ecological system to create new stability domain and fostering resilience in policies and responses. Folke et al. (2010) defines transformation as shifting any social–ecological system into new domain, and development trajectory when existing one is untenable with human and natural induced shocks and management failures. Transformation in any social or ecological system is triggered by particular extreme events, human induced over harvesting of resources like fishing and global warming.

The significant approach of transformation is common with resilience thinking that indicating crisis as an opportunity for development in social–ecological system. Disturbance is needed to integrate within coastal development as an opportunity and assessment of reorganization pace through social–ecological lens. In many coastal systems post-disaster social attributes including land tenure, access to resources, alternative livelihoods remain complicated governance issue and needs priority in adaptation plan for defining broader social–ecological framework. Decision-makers has opportunity for emphasising on scientific evidences and examining current capacity of coastal ecosystem to determine the threshold point before regime shift and select alternate states for future service generation. Non-linear behavior of coastal ecosystems is unavoidable due to increased human interventions aggravated climate related stress (Janssen and de Vries 1998). From single steady state to multiple basins of coastal ecosystems is growing management interest while developing coastal adaptation plan and maximizing potential values through ecosystem transformation.

Transformation in coastal areas is largely granted due to multi-scale interaction and regenerating capacity essential in natural and social sub-system for responding disaster and producing goods and services for human livelihoods (Adger et al. 2005a, b). Olsson et al. (2004a, b) identifies following three phases of transformation: current sources and factors around the social–ecological system to determine the changes required from crises; navigating the transition with past experiences and learning to assess the relative merits in new domain; and innovation practices for building resilience in new development trajectory. Coastal transformation requires engaging stakeholders for identifying climate change related problems and barriers to development and ultimately finding consensus solutions (Tompkins et al. 2008). The transformational changes of coastal ecosystems can start as majority of stakeholders agree that existing land use system is non-functional due to disaster and persistent environmental stress and they need new development trajectory.

Coastal transformation may begin from small ecological (mangroves) and social (i.e., fishermen) scale management to draw feedback effects and learning for managing large scale development options. While transformation is important to avoid stress and select new land use practices or natural resource management, there is counter challenges among winners and losers to optimise the outcome. The risks of any negative outcomes in new arrangement must be carefully planned with multi-stakeholder consultation to assess the outcome level with transparent navigation and foster resilience for broader social interests. Transformation can be led either by deliberative or forced way depending on scales of responses and preparation of the communities and institutions to shift into new regime. Salinity affected coastal lands can be transformed into productive regime by following small scale interventions at local level to leading gradual effects for large scale policy response. Change in subsidence and snow-melting induced erratic run-off is affecting deltaic regions and falls beyond the local and national management to broader institutional arrangement (Klein et al. 1999).

Transformational change in coastal ecosystems offers novelty in practices and adaptive decision making, shifting perceptions from conventional resource management approach to new networking and institutional arraignment to shape desirable trajectory in climate change context. Dietz et al. (2003) call for transformation of ecosystem management into adaptive governance for managing integrated social–ecological system. Coastal ecosystems need emphasis on extending management focus from conventional approach to adaptive governance that consists of heterogeneous interests of human agents and their networking. New policy and practices comprise integrated institutions for managing diverse actors and dynamic morphological and ecological changes into alternative regimes.

15.3 Innovative Coastal Land Use Pattern for Adaptation

Bangladesh government is currently implementing the first global LDCF adaptation (CBACC-CF) project to reduce climate induced vulnerability in coastal areas through enhancing resilience of communities and protective ecosystems (Nandy and Ahammad 2012). In the project, innovating coastal land use system for community, led interventions has been envisaged as key measures to reduce climatic vulnerability and enhance adaptation. The project has selected fallow govt. coastal lands to convert into multiple resource generation in Bangladesh. Most of these lands are biophysically formed by sedimentation deposit, stabilized with mangrove plantation and shaped into char lands. Mangroves stabilized part of these lands with vegetation, but a significant part of these lands remain underutilized due to less of suitability for afforestation, exposure to soil salinity and tidal inundation. Of these lands, only 40 % are cultivated with agricultural crop for single season (4–5 months). With inundation of neap and spring tides, soil-salinity grew higher in the lands for significant months of a year that neither agricultural practices nor afforestation with mangroves and main land species are possible. Irrigation of freshwater was also

Fig. 15.1 Periodically inundated and fallow coastal lands are arranged for ditch and dyke uses

scarce in dry season for cultivating agriculture and salinity reached higher in groundwater of the coastal zones (Rahman et al. 2011). There is fact that less than 30 % of coastal lands can be irrigated which is lower compared to average 50 % of the country (Mia and Islam 2005). The project has occupied these land type as otherwise underwent to encroachment by local elites and remain unproductive and inaccessible for marginalized and landless coastal people.

The new land use approach successfully restores substantial size of vacant, illegally occupied and periodically inundated coastal lands into productive resource regime in two coastal districts of the project sites. Substantial parts of these fallow lands were open access govt. property without ownership title and captured by local elites through encroachment for further deforestation (CBACC-CF 2012; Nandy and Islam 2010). As coastal people are affected with climate change related risks and lower land productivity as well as inequality of land distribution, there has been possible to optimize the highest uses of limited lands and involve climate change affected vulnerable people. The newly practiced livelihood interventions in the land use system multiply social and economic opportunities and benefit landless communities. The significant part of the approach is multiplication of land uses for forestation, fish and agricultural cultivation and livestock rearing activities and eventually developing participatory ownership to provide adaptation practices (Nandy 2011). Most of the land use in coastal areas is dominated by horizontal expansion of agricultural practices or fish culture by shrimp farming, which are also threatened with changing climatic risks. The approach opens for vertical land management for ditch fish cultivation at the lower level and vegetation with horticulture and forestation on the top of dyke.

Land use pattern is technically based on preparation of ditch and dyke structure by involving local communities (Fig. 15.1). There are pro-active opportunities for involving coastal communities at the initial stage of consultation and motivation at local level for their initial engagement in land preparation works. The project has strong emphasis on community involvement in successive steps of land preparation as community provides 50 % of the cost through their labors. Two way benefits are ensured in the development approach for immediate cash for work to subsistence families and subsequently long-term engagement with adaptation user groups.

Fig. 15.2 Vertical land use approach for coastal adaptation

The long-term land user groups are entitled to a one ditch and dyke after preparation for 10 years agreement with renewal opportunities depending upon performance.

The connected ditch and dyke structure has reduced salinity ingress in the agriculture lands during high tide (Fig. 15.2). Dyke vegetation with advanced agricultural crop and fruit varieties, and forest species renovated local land uses for sustaining provisioning services and conserving natural resources in environmentally constrained coastal areas. With the technical support of local govt. departments beneficiary families received training and improved crops, fruit seedlings, fingerlings and forest trees. All these are integrated with respect to seasons and suitability of land for cultivation. The combination of upper and lower land utilization is replacing one another for providing alternative livelihood measure to coastal communities, particularly for managing income risks in lean period or erratic shock appeared by heavy precipitation or tidal inundation.

With the support of local institutions, community ownership on 112 ha of coastal lands (stabilized char lands behind mangrove forest) has been arranged for income generation of landless and marginalized families. The collaborative livelihood arrangement accommodates 8–10 families/ha and appears as rational land use (Nandy 2011). The level of association in the project implementation and competing interests among local agencies influence their roles in land use integration. The implementing local govt. departments considered that the livelihood of people living surrounding mangrove plantation areas highly depends on climate sensitive sectors like agriculture, forestry, fisheries and livestock. The impact of climate change to these sectors contributed to the low adaptive capacity of these coastal communities. Though about 60 % of people are directly involved with agricultural activities in coastal areas, 30 % of them have only homesteads or no land.

This newly developed land use practices explored options for income generation and sustaining flow of resources (Nandy and Ahammad 2012). The new land use technique increased manifold production from agriculture in raised dyke system over traditional and highly rain fed cropping. Given the land use pattern, a family increases household adaptive capacity through generating at least $1,000 USD/family/year additional income in addition to their routine livelihood activities. There are currently used these fallow lands for short-term, mid-term, mid to long term and long term basis. While considering time variation for protection of land use is contributing to the recurrent income generations that ultimately leads to the livelihood sustainability and increase the adaptive capacity of these poor coastal communities. Since the project begins land ownership has been transferred to coastal communities with tenure for diversified livelihood practices. The land use model is framed for diversifying livelihood in ditch and dyke system to promote adaptation practices. In each hectare of lands, eight (8) ditches and nine (9) dykes are developed and distributed to 8 families for ten (10) years land ownership agreement with renewal opportunities depending upon beneficiary performance. The significant part of this approach is community providing 50 % of the labor cost by working themselves in earth excavation for ditch and dyke development.

15.3.1 Synergies of Coastal Land Use for Ecosystem Based Adaptation

Ecosystem-based adaptation promotes the arrangement of adaptation policies and measures that take into account the role of ecosystem services in reducing the vulnerability of society to climate change, in a multi-sectoral and multi-scale approach (Vignola et al. 2009). The current experience shows the potential lessons of EBA approach in Bangladesh through land restoration for critical ecosystem services with social and ecological opportunities of coastal communities and mangroves. Coastal ecosystems are traditionally managed under fragmented institutional responses for land, water and mangrove forest resources without understanding conservation and generating important ecosystem services for adaptation in Bangladesh. Integrating adaptation measures through innovative and diversified coastal land use with afforestation and community led livelihood practices can be producing sustainable goods and services (Nandy 2010; Nandy and Ahammad 2012). The project integrates mangrove land restoration and alternative user values for producing ecosystem goods as adaptation measures to coastal communities. Some salient features of the land use practices with potential scopes for EBA can be protective land use; facilitating transformation of the practices; community integration within ecosystem functioning at temporal and spatial scale for flexible decision-making and participatory local resource development; multi-stakeholder institutional space; adaptive management etc.

15.3.1.1 Protective Land Use and Conservation for Coastal Adaptation

Coastal natural resource uses dominate primarily subsistence agriculture for food production, e.g. rice cultivation along with some cash crops, and coastal fisheries, which provide a major food and income source. Of the 2.85 ha of total cultivable coastal lands, not less than 1 ha remains fallow and unproductive for generating ecosystem services due to salinity in dry seasons and lack of fresh water (Karim et al. 1990). The rain fed *Aman* is the dominant single rice crop traditionally used by coastal communities. Due to chronic threats of extreme climatic events, even minor changes in seasonal precipitation and salinity intrusion large sizes of coastal lands remain less productive for cultivation more than single crop (Rahman et al. 2011). Anthropogenic activity of shrimp farming and salt pan also caused severe land degradation with loss of natural mangroves and biodiversity in south-west and east coastal zones (Islam and Ullah 2012). From 1980 to 2000, shrimp farming has rapidly increased and caused conversion of approximately 141,353 ha of agricultural lands and adjacent natural mangrove areas (Bala and Hossain 2009). The extensive use of shrimp culture techniques and salt intrusion largely disturbed natural soil-salinity balance in coastal ecological system. As result, loss of natural mangroves is highly likely to threaten the subsistence livelihoods of marginalized group and primary habitat of shrimp fry and other fishes. All these problems affect with different degree of intensity where careful planning and preventive measures in coastal land management reflect the co-evolving human and natural system for EBA.

Extreme events with climatic variability are reducing the ecosystem functions and social-economic activities for human well-being (Alongi 2008). EBA practices refer to shift development thinking from conventional coastal land management to community based conservation regime. Land use in coastal zone requires crop selection/development of salt resistant variety and diversification of the practices to ensure the protective land use and maximum benefit for communities (Bala and Hossain 2009). Conventional coastal afforestation programme is rarely focusing on dynamic biophysical and social changes around mangrove lands and management at broader landscape level in coastal areas (Nandy and Ahammad 2012). Considering factors like increasing population, changing economic activities, competing land-uses and low return from forest trees, alternative use of coastal lands in more profitable way are part of scientific investigation and policy as well as important for adaptation (Iftekhar and Takama 2008). Restoration of coastal lands around natural and planted mangroves and integration within dynamic uses are not only matter of avoiding critical threshold of the resources, but also to sustain the alternatives services for future.

Bangladesh is a land scarce country and relocation of vulnerable coastal people or abandoning the existing practices will not be pragmatic solution for disaster risk reduction and adaptation (Saroar and Routray 2012). Coastal land restoration and conservation for producing ecosystem goods and services is as essential as for protection of critical resources and sustaining productive roles for adaptation. Coastal lands can be well conserved through mangrove plantation in the first place, whereas stabilized lands requires additional protection measures for avoiding excessive inundation and salinity intrusion risks and improving new livelihood practices. The current land use practice opened how to rehabilitate coastal lands for conservation by integrated natural resource management including agricultural vegetation, forestation and fish cultivation. Improving land use with the cost-effective arrangement can be productive not only for community resources as well as drawing local institutional responsibilities to combined conservation efforts.

Communities perceive rehabilitation of degraded coastal lands can be “win–win” strategy for accruing conservation benefits by using natural resources to produce adaptation resources around them. The finding of Saroar and Routray (2012) is consistent for further connotation with the new land use innovation of the project. The study has identified the negative relationship of psychosocial adaptation with land holding of coastal people in Bangladesh. Influential factors to adaptation efficacy against the impacts of climate change and sea level rise are farmland holding, the habit of contacting local officials, frequent adaptation against salinity intrusion, and “drier conditions”. People who have farmlands are less capable meaning their inability to maintain the values of coastal lands in terms of productivity and price confronting climate change threats. There is growing perceptions among coastal people that the risk from permanent inundation by saline water must degrade the quality of their land parcels. New sense of integrating key natural resource management within the land use will raise awareness among the large land holders and marginalized groups for conservation and maintain EBA beyond large scale climatic threats.

15.3.1.2 Building Land Ownership and Sustainable Livelihoods

Coastal land occupancies and use have taken place without little concern for sustainable livelihoods and practically no integrated planning at the national or, even less, international level in the last few decades (Cendrero 1989). Strict regulation on non-destructive land use can balance over exploitation and promoting protective and innovative livelihoods can consider the coastal dynamics as whole and particular social, ecological and economic benefits for local communities. Hadley (2009) notes that uncertainties of sea level rise, flooding and erosion impacts are difficult to assessment though the competition is increasing between intertidal habitats and coastal grazing marsh, and between competing human land uses, e.g. aquaculture, recreational, commercial and agricultural uses. Coastal communities have limited access to diversified land use techniques or improved agricultural crop varieties and usually depend on seasonal fishing only. Pre-existing national policies of Bangladesh permits land rights to marginalized and landless groups only, which has no practical enforcement and regulation in resource access and use of the associated ecosystem services. The land use model provides rights and rational use pattern as key to local and national compliance of the policies and long-term livelihood development of coastal communities.

Adaptation programme has key challenge to secure land rights, adaptive livelihoods or generally to say income generation sources in ecological fragile areas. Coastal communities largely depend on climate sensitive natural resources including agriculture and fish as the major livelihoods. Adaptation strategies must need to involve the mobilization of livelihood assets, networks, and social capital to anticipate and to react to potential disasters (Adger et al. 2005a, b). The decentralization policy experience in Indonesia and Brazil promotes community participation for coastal ecosystem management without empowering user groups and capacity building to access right which eventually excludes highly resource dependent groups from livelihoods and equity within existing social structure at the local level (Wever et al. 2012). In the context of EBA, reformation or new land use is not sufficient to promote adaptation until addressed the sustainability, integration and values of community participation in livelihood management. The expense of land restoration technique or conservation should not ignore co-benefits of vulnerable and natural resource dependent communities whose livelihoods are at risk in coastal areas.

Building ownership and engaging local community in participatory form of land management can be significant step towards EBA in coastal areas of Bangladesh. The land use opens new paradigm of coastal resource management to draw synergistic effects from both ecosystem and community level through conservation for livelihood development. Livelihood practices are arranged in proactive manner and considered with climate change related variability in sensitive seasons and years; and as a result protective income generation at different time scales. Different types of livelihood practices are not seen as isolated management units within the ditch-dyke arrangement rather integrated for drawing positive interaction and benefiting at ecosystem level. For instance, rain water harvesting and irrigation increase fresh water fish cultivation to coastal people which is securing additional income replacing lower agricultural land productivity and thus enhancing critical household resilience. There is the fact that different households have different livelihood strategies which they choose from their experiences and choice of profit. The diversity in livelihood strategies is considered through mobilizing community experience, sharing knowledge and transfer of new information related to climate change risk to land uses, and thereby improves diversity of income generation.

15.3.1.3 Transformation of Desirable Coastal Land Use System

Transformation of coastal ecosystem management from undesirable state trapped with disaster shocks (Adger et al. 2005a, b), landlessness and poverty to beneficial land use practices create forward looking to EBA in climate change context. In the first stage of transformation, most of the coastal communities and service providing institutions identified that the previous land use was dysfunctional and highly sensitive to disaster shocks and salinity intrusion. Local stakeholders agreed on the social inequity in coastal land access and undefined management system and lack of alternative livelihood system with mangroves as barriers to sustainable resource generation. Land use innovation and ownership pattern in the new system is currently understood as essential steps for transformation toward climate change risk management. Reconfiguring coastal land use in this ways also necessitates a new learning and deliberation space for accommodating expanding environmental, societal and institutional needs (Lloyd et al. 2013). This type of transfer for a land-based ecosystem planning can provide greater understanding of coastal–marine land dynamics, inter-relations and stakeholder–community interactions.

Climate awareness and motivation to effective land use influences people's adaptation efficacy against climatic stresses (Saroar and Routray 2012). The new adaptation initiative improved livelihood practices and social equity in resource generation and thus initiated new roles among community and institutions to adopt the system in the long-run (Nandy and Ahammad 2012). Community's transformation towards EBA and conservation practices is related to how they are defining stress, participating and receiving new information and adjusting to improved land use practices. Though socially constructed and informal cultural legacy often determines their voluntary transformation capacity, it can happen through informal networking of individuals and collective manner with respect to the ecosystem based approach (Olsson et al. 2004a, b). The successful adaptation experience from small groups to cross-learning can cause a transformation of the innovation among the participated members and coastal community. Large scale acceptance of the land use system over fallow lands requires major changes in irrigation, fertilizing and quality seeds and fishes for producing additional income sources.

Nandy et al. (2003) emphasized on legal relationship, mutual trust and land ownership are significant parts of building participatory resource management in mangrove ecosystems. This is also the possible case in the project that developing trust and network between local community and institutions to deploy the innovation practice (Nandy and Ahammad 2012). Most important is developed deliberative and voluntary roles of community for protection of mangroves. In fact, the land ownership arrangement triggered the participated community's role for protection of their own livelihood resources and adjacent mangroves. Bangladesh Forest Department has one Forest Guard for guarding approximately 3,015 ha. of coastal forests. The participant beneficiary of the land use acts as "Watch Dog" for reducing illegal destruction of the forest plants and products. Beneficiaries have added supplementary strength to FD's institutional existing capacity for protection of coastal forests. The current experiences will be significant transformation change at local scale for incorporating voluntary role of community in future management activities of the Forest Department.

Identification of potential land use and additional income generation provides opportunity to transformation of local institutions for distributing ownership to coastal communities. Despite local land offices are not aware on sustainable land uses in coastal areas; the current experiment improves their capacity to facilitate other government department for equitable ownership distribution. But, there is also uncertainty in outcomes of innovation as new benefits can by captured by local elite and diverse interested social groups in coastal areas (Hadley 2009; Lebel 2012). Such constraints and drawbacks are well considered through enabling legislation, financial, political and moral support for land ownership. National institutions are currently revising land use policy in particular for initiatives to coastal land management.

15.3.1.4 Participatory Decision-Making

Community based approach of the project focused much on developing partnership with diverse stakeholders in order to ensure the successful implementation of the adaptation interventions. The project is involving local community in participatory afforestation and livelihood interventions. People's opportunities and capabilities to make and express choices and to transform land uses into desired actions and outcomes are vital to effective project design and implementation and perhaps more importantly to their sustainability (Sieghart and Ganapin 2011). This is important to know how individual and households have sufficient information on climatic risks and access to take decision for managing new practices and profits. People in the coastal area need to be prepared for anticipatory adaptation against such impacts based on current knowledge and scientific advances concerning sea level rise. History of community based assessment also supports the ability of collective action depends on common goal and vision under the new landscape structure and services generated to them (Berkes et al. 2003; Quinn et al. 2007). The land use initiative involved community members irrespective of their social and economic position in developing local adaptation management plan for implementing the model in particular project sites. The community beneficiaries identified vulnerable groups who can be benefited; their key resources at risk; most demanding assets and potential alternative measures to be implemented for their long-term adaptation.

The initiative emphasized on the needs of target community within resource distribution, and best fit of the project interventions locally as well as required institutional supports. There was always open decision making process among involved community, Co Management Committee members and local institutions to ensure that marginalized and women groups are included in resource distribution and management. Noteworthy that participatory land distribution has opened women's access to collective assets and income generation and their involvement in decision making process. While the project addresses climate change as key threat to coastal ecosystems, it also considers landlessness is much affecting capacity of ecosystem service generation and eventually livelihood security of community.

15.3.1.5 Navigating Adaptive Institutions

Institutions provide rules and strategies by which societies interact and use their traditional ecological knowledge to produce a livelihood from ecosystems to adapt to shocks in their environment (Folke et al. 2007). The distribution of roles among diverse stakeholders across scales improves institutional networking and flexible governance for equitable resource delivery in coastal areas. The shifting land management from illegal occupation and encroachment to collective ownership opened community bonding and trust with institutions and raising self-contribution to conservation and managing livelihoods. Drawing experience of the community based land use approach as starting point, local government can provide motivation elements to national level for opening further opportunities of mainstreaming, replication, and upscaling the potential EBA initiative. Guiding community for land regulation, restriction on over exploitation and inclusive resource governance; improving services for infrastructures, health and education, and providing new leadership through bringing new information and experiences within community and outside stakeholders to draw comparison and avoid pitfalls in the practices are some of the influential elements for local institutions to motivating climate protective land use (Staden 2010).

Broadly access to local institutional services has improved community capacity to integrate climatic information in their continuous land use and livelihood development and avoid current and anticipated risk management. There is largely possible to bring adaptation practices for ensuring resilient livelihoods through improved crop and fish varieties to absorb shocks without downsizing the regular functions. Disaster and climate change related risks are currently well addressed as shared responsibility among service providing institutions including Forest, Agriculture, Livestock and Fisheries Department. The land use initiative attempts to draw institutional interface for providing climate change information and related critical services in integrated manner to minimize the adaptation costs. The local Co Management Committee is currently acting as collaboration interface among implementing government departments to share and understand the contingent risk management and transfer of adaptation services. However, a robust institutional arrangement to enhance synergistic effects of adaptation services of the local institutions with coastal community is under-addressed in the initiative (Adger et al. 2005a, b).

EBA policy needs flexible social–institutional interface over rigid social systems for resource use and following learning by-doing approach to enhance long-term climatic risk management. Adaptive institutions are based on integrative ecosystem management approach for experimentation of management policies and learning to draw long-term adaptation effects (Folke et al. 2007). This fosters evolving coastal policies and institutional framework to anticipate climatic uncertainty with participation of diverse stakeholders. Bangladesh broadly faces challenges in institutional, organizational, and human resources at national and sub-national levels to maximize new climate funds and ecosystem based approach in adaptation programmes. The case experience reflect unclear role of local government departments (especially at District and Upazila levels) to take advantage of EBA by extensive land restoration for design of cost-effective adaptation.

The decentralized institution approach for EBA is necessary, but not sufficient for ensuring democratic and sustainability of community based land use policy reform. Without local responsibilities based on democratic involvement of coastal populations and accountability of institutions lead to further disempowerment of already marginalized social groups (Wever et al. 2012). The CBACC-CF project can be first attempt to strengthen local government capacity in understanding land use crisis as a window of opportunity for effective adaptation service delivery. There is yet much to draw learning and knowledge on best practices and capacity from horizontal to vertical institutions for designing more effective land use practices in coastal areas. Supported by the project, coastal land use policy is reviewed to delineate land ownership among public and private stakeholders and design site specific land uses for afforestation, agriculture and aquaculture, which are also key to facilitating EBA.

15.3.2 Protective Ecosystems, Mangroves and Mitigation

Ecosystems are biologically diverse natural habitats and significant carbon stocks for climate change mitigation. Carbon accumulation and sequestration is related to the types of ecosystems, species diversity and land management. At global level, aquatic and terrestrial ecosystems are estimated to be storing higher 38,000 and 2,500 Gt Carbon respectively compared to only 750 Gt atmospheric carbon content (Secretariat of the Convention on Biological Diversity 2009). Coastal ecosystems possess diverse source of carbon capture than others through plant above and below sea level as well as soil. There is a multi-time frame of carbon accumulation benefits in coastal ecosystems which are related to organic bearing or peat like soil binding, plantation growth and quality of freshwater and salt water marshes and seagrass bed in the long-run.

Conservation of biodiversity and restoration in degraded terrestrial, freshwater and marine ecosystems is widely recognized by Convention of Biological Diversity (CBD) as well as key measures to maintain functions for favorable carbon cycle which is significant part of mitigation goals of UNFCCC and providing adaptation benefits and achieving Millennium Development Goals (MDGs). The recent climate change agreement Reduced Emissions from Deforestation and Degradation (REDD+) is a new guideline which emphasizes on national carbon stock assessment and relatively cost-effective option for mitigating climate change through forest conservation (for example, carbon credits). In this view, EBA can be appropriate measure for enhancing carbon sink through conservation of natural and planted forests and restoration of existing coastal wetlands as well as improved land management.

Coastal ecosystems contribute to global mitigation due to its cost-effective land transformation from barren or grass lands into forest vegetation. The most effective way to maintain coastal ecosystems' carbon pools is avoiding degradation and conversion through protection and sustainable management. For instance, protection and conservation of coastal wetlands through mangrove plantation has immediate benefits for soil binding and transferring oceanic carbon into sediment and developing woody biomass to store carbons. There is yet not available estimation of actual mangrove coverage and also improved technique to assess the loss at local level. The global loss of mangrove has been estimated around 20 % between 1980 and 2005 (Crooks et al. 2011). Sustainability of mangroves either in natural or plantation forms is increasingly important management issue to reduce deforestation and carbon emissions. Global forest areas is being cleared at the rate from 7 to 13 million ha annually which releases 1.5 Gt C (5.5 Gt CO_2) into atmosphere. The potential measures must be related to appropriate land management practices for

Fig. 15.3 Afforestation techniques for enhancing resilience of protective coastal ecosystems

afforestation, sustainable forest management and restoration of degraded forest habitats including coastal wetlands.

EBA approach addresses deforestation as an important part of forest management for drawing comparison between the current forest loss and afforestation measures to be taken for enhancing mitigation efforts. The clear estimation and baseline of deforestation can be indicative tools and guidelines and decide the forest habitats which can be managed under reforestation and also assess the carbon emission rate. Bangladesh has only 2.52 million ha forest coverage which is 10 % of the total lands. Though Bangladesh has less contribution of global GHG emission, annual loss of forest areas has been estimated on average of 2,600 ha between 1990 and 2010. Afforestation and suitable reforestation or enrichment planting is much required to check the deforestation rate and at the same time to improve ecosystem functions. Mangrove afforestation has already got momentum for protection and conservation of exposed newly accreted coastal lands. Compared to any other forest types, mangroves is one of the carbon dense forests where Bangladesh can amplify the benefits towards global carbon sequestration by afforestation and increasing forest coverage in new lands and reducing deforestation. The CBACC-CF project has been very efficient in implementing mangrove afforestation programme in more than 3,000 ha annually that exactly corresponds to the annual changes in forest cover of Bangladesh and such contributes to global mitigation efforts (Fig. 15.3).

While forest degradation is increasing there is required appropriate conservation measures and restoration in natural forests to reduce biodiversity loss and carbon emission. Natural forests are more carbon dense and biologically diverse than other modified and planted forest ecosystems. It can be noted that protected areas contribute to 15 % of terrestrial carbon sequestration. Conservation of protected area and including natural and planted mangroves can improve forest habitats with species and genetic diversity while also increasing carbon sink capacity in Bangladesh. The Integrated Protected Area Co Management (IPAC) is currently taking initiatives in different protected forests for conservation and increasing carbon stock enhancement, such as: (a) 6.4 million ton CO_2 emission reduction by Collaborative REDD + Improved Forest Management (IFM) Sundarbans Project (CRISP); (b) 760,000 t carbon stock enhancement by Chunati Wildlife Sanctuary Management of Natural Resources and Community Forestry (MNRCF) project; (c) 414.87 million t CO_2 emission reduction by Bangladesh REDD + Afforestation, Reforestation and Revegetation (ARR) in Protected Areas Project (BRAPAP). The CBACC-CF project is implementing mangrove afforestation in 9,100 ha of coastal lands. During the project pilot phase, mangrove plantation will add to existing forest coverage and contribute to about 910,000 t carbon storage capacity.

Degradation of coastal ecosystems through land use changes and conversion of mangroves for agricultural cultivation and shrimp farming reduces above and below ground carbon pools. Mangrove is the highest mean carbon sequester in the tropic indicating the largest mitigation benefits from the ecosystem type than any other forest domains in the world (Donato et al. 2011). Mangrove afforestation in new coastal lands can increase above and below ground carbon stocks by protective vegetative covers. In addition to that reforestation within existing mangrove stands can support ecosystem capacity to regenerate functions that itself acts as EBA and continue carbon sequestration. Carbon storage capacity of mangrove species varies between above and below ground with respect to spatial locations and varying salinity, soil depth and water management. The whole ecosystem based carbon stocks of mangroves can be even larger if properly managed by improved land management techniques, alternative financing for carbon trade for protection of forest as co-benefit of EBA.

The combined effects of sea-level rise and anthropogenic stress on mangroves is poorly understood (Gilman et al. 2008) where EBA can offer advanced assessment on consequences; management options and strategic planning for functional linkage within ecosystem levels. Rehabilitation of degraded mangroves can improve habitat quality and biodiversity which are important for ecosystem functions to adaptation and keeping up mitigation. Mangrove afforestation can improve carbon flux rates in coastal ecosystems by properly assessment of species initiation, regenerative diversity and gap management. Keora (*S. apetala*) is pioneer species for land stabilization in coastal ecosystems and contributing to carbon sequestration in mangrove plantation management of Bangladesh. The 5–15 years old *S. apetala* forest stands are currently losing regeneration capacity and weakening vegetative coverage and reducing carbon stocks. Nandy (2010) pointed out the mangrove gaps through enrichment planting with mixed and complex plantation to aid regeneration. There are different ten commercially important mangrove species introduced as enrichment planting under CBACC-CF project. The afforestation approach is not only important for improving species diversity and protecting carbon storage, but also have potential aspect of EBA for sustaining ecosystem services in coastal areas.

15.4 Sustainability: Way Forward

Coastal ecosystems are increasingly facing complex system, rapidly changing and evolving with novel responses of social and ecological variables. Decision-makers shift on a long-array from traditional disaster risk reduction approach to integrated coastal zone management (Vellinga and Klein 1993; Shaw and Krishnamurthy 2012) and currently climate change adaptation for vulnerable groups, countries and states. The most challenging issue is why previous protective measures failing to effectively manage coastal resources and create spillover effects on environment; and how current actions can influence sustainability actions confronting climate change related stress like sea level rise within short to long-term actions. There are differences between level of actions developed and context of interplay; type of ecosystem conserved to alternative profit regime; and participatory resource ownership over enforced institutions is largely determining coastal sustainability and EBA. Integrating assessment of social, ecological and morphological components for comprehensive coastal planning are important though challenging research task is ensuring easier communication of the findings to decision-makers, public and interested sectors (Klein et al. 1998, 2003). Vellinga and Klein (1993) looked into Integrated Coastal Zone management (ICZM) through holistic approach considering the complex factors; understanding diversity of interests in sustainable use of coastal resources; and defined institutions roles involved across international, regional, national and local levels.

Diverse knowledge from pilot based research findings is effective for design of coastal development plan (van den Bergh and Nijkamp 1998). The land use innovation for adaptation practices in coastal ecosystems open transformation of thinking and approaches in resource management. From current experience, successful transformation of land use practices towards sustainability could be promoted by fostering the innovation and building adaptive capacity and resilience. Transforming land use innovation must follows three dimensions: direction of change, diversity and distribution to be considered in sustainable development (Leach et al. 2012). The benefits of land use must be guided within specific goals and principles and integrating the differences (mangrove protection and shrimp culture will differ) along the pathway to drive with the more robust adaptation directions. Diversity of land uses approaches, livelihood strategies, and institutions provide a richer resource regime to foster more robust and resilient innovation pathways into the future. The land use innovation will not be important adaptation until the potential space is shared among the stakeholders to identify who gains and lose from the new policy and eventually navigating the trajectory. New land use system is emerging and yet to proliferate the benefits at large social and ecological scale for EBA.

Much emphasis should be given to strengthen social equity in new resource management, fostering common values among interested groups on planned benefits of land restoration and empower the key stakeholders in decision making to legitimate their relationships.

The novel experiment requires trust building while resolving competing interests in new arrangement to enhance resilience. In the current land resource management system, not only coastal community understands climate change and disaster risks collectively, but they also develop participatory resource management for sharing benefits in the long-run. Community perceives the land use practice can sustain long-term resource generation due to multi-scale income options and protective ecological infrastructure by mangroves. The additional coastal lands can be transformed within future livelihood arrangement considering the cost-effective approach of the current practice and ecosystem based community integration for livelihood in coastal areas. But, ensuring institutional support in the land use practice and resource distribution in the project sites remains critical challenge in prior to resolving competitive interests in local land and water grabs and profitable business; and poverty reduction and sustaining coastal ecosystem services for instance. There are reasons due to overridden land rights on coastal lands create management loophole and user conflict in implementation of the current initiative.

Coastal land ownership is socially constructed with institutions involved for isolated management goals benefiting particular social groups than those who need urgent livelihoods in the adaptation model. National land use policy and ICZM approach inadequately defines local institutions for coastal land management and improves capacity for risk reduction measures. Coastal land zoning is prepared until now without institutional integration to share climatic risks as "shared roles" and developing participatory livelihood. Bangladesh Climate Change Strategy Action Plan (BCCSAP), NAPA, PRSP, MDGs and other relevant development programme focused on integrated and sustainable coastal development strategy. The policies yet lack in comprehensive and practical guideline for institutional integration mechanism in development projects. Most of the adaptation programmes are limited within isolated livelihood inputs for agriculture, fisheries or health related sanitation measures to individual households. Compared to these, the land use experience opens integrated ecosystem management approach with multi-stakeholder collaboration space for cost-effective adaptation options at community. The community involvement for protection and conservation of coastal land resources including mangroves and sustaining small-group based resource generation can be considered for taking account to promote EBA.

The immense complexity of the bio-geophysical and human activities in coastal zone regions remains a difficult management task for adaptation interventions. Sea level rise will create major problems to coastal ecosystems for sustainable land use and eco-engineering protection practices in Bangladesh (Ali 1996; Sorwar 2005). Scenarios of sea level rise and associated impacts on dynamic coastal ecosystems need to be as accurate as important for drawing sustainable approach in current adaptation design. We must seek socially and naturally feasible strategies based on sound spatial-economic and environmental database, various functions of coastal zones, definition of the competence of and opportunities for both private and public actors, and most of all a behaviour-oriented analysis of resilience strategies in coastal zones (van den Bergh and Nijkamp 1998). Mostly in Bangladesh, assumption of sea level rise and associated water stress are not adequately addressed in mangrove restoration, current land use practices and water resource management. That is why understanding sustainability is important for opening renewal opportunities of social and ecological resource management in dynamic coastal ecosystems (Adger et al. 2005a, b). By drawing experience of current land use based adaptation practice we can draw synergies and relate to wider social, environmental and economic opportunities for EBA in Bangladesh.

References

Adger WN (2000) Institutional adaptation to environmental risk under the transition in Vietnam. Annals of the Association of American Geographers 90:738–758

Adger WN (2003) Social capital, collective action, and adaptation to climate change. Economic Geography 79(4):387–404

Adger WN (2006) Vulnerability. Glob Environ Chang 16(3):268–281

Adger WN, Arnell NW, Tompkins EL (2005a) Successful adaptation to climate change across scales. Glob Environ Chang 15(2):77–86

Adger WN, Hughes TP, Folke C, Carpente SR, Rockstrom J (2005b) Social-ecological resilience to coastal disasters. Science 309:1036–1039

Adger WN, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson DR, Naess LO, Wolf J, Wreford A (2009) Are there social limits to adaptation to climate change? Clim Chang 93:335–354

Agrawal A, McSweeney C, Perrin N (2008) Local institutions and climate change. The Social Dimensions of Climate Change No 113, World Bank, Washington, DC

Agrawala S, Ota T, Ahmed AU, Smith J, van Aalst M (2003) Development and climate change in Bangladesh: focus on coastal flooding and the Sundarbans. OECD Publications, p 70

Ali A (1996) Vulnerability of Bangladesh to climate change and sea level rise through tropical cyclones and storm surges. Water Air Soil Pollut 92:171–179

Allen KM (2006) Community-based disaster preparedness and climate adaptation: local capacity-building in the Philippines. Disasters 30(1):81–101

Alongi DM (2008) Mangrove forests: resilience, protection from tsunamis, and responses to global climate change. Estuarine Coast Shelf Sci 76:1–13

Bala BK, Hossain MA (2009) Integrated management of coastal zone for food security. Final Report CF 5/07, p 134

Berkes F, Folke C (eds) (1998) Linking social and ecological systems: management practices and social mechanisms for building resilience. Cambridge University Press, Cambridge

Berkes F, Colding J, Folke C (eds) (2003) Navigating social-ecological systems: building resilience for complexity and change. Cambridge University Press, Cambridge, p 393

CBACC-CF (Community Based Adaptation to Climate Change Through Coastal Afforestation) (2012) Homepage. www.cbacc-coastalaffor.org.bd. Last accessed 6 June 2012

Cendrero A (1989) Land use problems, planning and management in the coastal zone: an introduction. Ocean Shoreline Manag 12:367–381

Christoplos I, Anderson S, Arnold M, Galaz V, Hedger M, Klein RJT, Goulven KL (2009) The human dimension of climate adaptation: the importance of local and institutional issues. Commission on Climate Change and Development, Ministry for Foreign Affairs, Stockholm, p 38

Cinner JE, McClanahan TR, Graham NAJ, Dawc TM, Maina J, Stead SM, Wamukota A, Brown K, Bodin O (2012) Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. Glob Environ Chang 22:12–20

Crooks S, Herr D, Tamelander J, Laffoley D, Vandever J (2011) Mitigating climate change through restoration and management of coastal wetlands and near-shore marine ecosystems: challenges and opportunities. Environment Department Paper, 121, World Bank, Washington, DC, p 69

Cutter LS, Barnes L, Berry M, Burton C, Evans E, Tate E, Webb J (2008) A place-based model for understanding community resilience to natural disasters. Glob Environ Chang 18:598–606

Dietz T, Ostrom E, Stern P (2003) The struggle to govern the commons. Science 302:1907–1912

Donato DC, Kauffman JB, Murdiyarso D, Kurnianto S, Stidham M, Kanninen M (2011) Mangroves among the most carbon-rich forests in the tropics. Lett Nat Geo-Sci 5

Ensor J, Berger R (2009) Community-based adaptation and culture in theory and practice. In: Adger WN, Lorenzoni I, O'Brien K (eds) Adapting to climate change: thresholds, values, governance. Cambridge University Press, Cambridge, pp 227–239

Folke C (2006) Resilience: the emergence of a perspective for social–ecological systems analyses. Glob Environ Chang 16:253–267

Folke C, Hahn T, Olsson P, Norberg J (2005) Adaptive governance of social–ecological systems. Ann Rev Environ Resourc 30:441–473

Folke C, Pritchard L, Berkes F, Colding J, Svedin U (2007) The problem of fit between ecosystems and institutions: ten years later. Ecol Soc 12(1):30. http://www.ecologyandsociety.org/vol12/iss1/art30/. Accessed 30 July 2012

Folke C, Carpenter SR, Walker B, Scheffer M, Chapin T, Rockström J (2010) Resilience thinking: integrating resilience, adaptability and transformability. Ecol Soc 15(4):20

Fussel MH (2007) Adaptation planning for climate change: concepts, assessment, approaches, and key lessons. Sustainability Science 2:265–275

Gilman EL, Ellison J, Duke NC, Field C (2008) Threats to mangroves from climate change and adaptation options: a review. Aquat Bot 89:237–250

Hadley D (2009) Land use and the coastal zone. Land Use Policy 26:198–203

Hossain AM, Reza MI, Rahman S, Kayes I (2012) Climate Change and its impacts on the livelihoods of the vulnerable people in the Southwestern coastal zone in Bangladesh. In: Filho WL (ed) Climate change and the sustainable use of water resources. Springer, Berlin, pp 237–259

Iftekhar MS, Takama T (2008) Perceptions of biodiversity, environmental services, and conservation of planted mangroves: a case study on Nijhum Dwip Island, Bangladesh. Wetlands Ecol Manag 16:119–137

Ingram CJ, Franco G, Rumbaitis-del Rio C, Khazai B (2006) Post-disaster recovery dilemmas: challenges in balancing short-term and long-term needs for vulnerability reduction. Environ Sci Policy 9:607–613

Islam RM, Nandy P (2001) Site suitability of different mangrove species and planting techniques for Baen (*Avicennia officinalis*) in the coastal areas of Bangladesh. In: Siddiqi NA, Baksha MW (eds) Mangrove Research and Development. Bangladesh Forest Research Institute, Chittagong, pp 39–48

Islam MS, Ullah MH (2012) Ecohydrology: a framework for overcoming the environmental impacts of shrimp aquaculture on the coastal zone of Bangladesh. Ocean Coast Manag. doi:10.1016/j.ocecoaman.2012.03.014

Janssen MA, de Vries HJM (1998) The battle of perspectives: a multi-agent model with adaptive responses to climate change. Ecol Econ 26:43–65

Karim Z, Hossain SG, Ahmed M (1990) Salinity problem and crop intensification in the coastal region of Bangladesh, BARC, Dhaka. In: Bala BK, Hossain MA (eds) Integrated management of coastal zone for food security. Final Report CF 5/07, p 134

Klein RJT, Smit MJ, Goosen H, Hulsbergen CH (1998) Resilience and vulnerability: coastal dynamics or Dutch dikes? Geogr J 164(3):259–268

Klein RJT, Nicholls RJ, Mimura N (1999) Coastal adaptation to climate change: can the IPCC Technical Guidelines be applied? Mitig Adapt Strat Glob Chang 4(3–4):239–252

Klein RJT, Buckley EN, Nicholls RJ, Ragoonaden S, Aston J, Capobianco M, Mizutani M, Nunn PD (2000) Coastal adaptation. In: Metz B, Davidson OR, Martens JW, Van Rooijen SN, Van Wie McGrory L (eds) Methodologies and technological issues in technology transfer. A Special Report of IPCC Working Group III. Cambridge University Press, Cambridge, pp 349–372

Klein RJT, Nicholls RJ, Thomalla F (2003) Resilience to natural hazards: how useful is this concept? Environ Hazards 5:35–45

Leach M, Rockström J, Raskin J, Scoones I, Stirling AC, Smith A, Thompson J, Millstone E, Ely A, Around E, Folke C, Olsson P (2012) Transforming innovation for sustainability. Ecol Soc 17(2):11, http://dx.doi.org/10.5751/ES-04933-170211. Accessed 20 Dec 2012

Lebel L (2012) Governance and coastal boundaries in the tropics. Curr Opin Environ Sustain 4:243–251

Lloyd MG, Peel D, Duck RW (2013) Towards a social–ecological resilience framework for coastal planning. Land Use Policy 30:925–933

Mia AH, Islam MR (2005) Coastal land uses and indicative land zones. Working Paper, WP040. Program Development Office For Integrated Coastal Zone Management Plan (PDO-ICZMP), Bangladesh

Naess OL, Bang G, Eriksen S, Vevatne J (2005) Institutional adaptation to climate change: flood responses at the municipal level in Norway. Glob Environ Chang 15:125–138

Nandy P (2003) Technologies and information generated for coastal afforestation in Bangladesh. Bulletin of Plantation Trial Unit Division, Bangladesh Forest Research Institute, p 19

Nandy P (2010) Climate resilient and sustainable coastal development in Bangladesh. Paper presented at 5th Nat. Conf. on Coastal and Estuarine Habitat Restoration, held on November 13–17, 2010, Galveston. http://www.estuaries.org/conference-2010-proceedings.html

Nandy P (2011) Forest, Fish and Fruit: new model of climate change adaptation in Bangladesh. In: Abstract, 5th international conference on community based adaptation to climate change (CBA5), held at Dhaka, p 188

Nandy P, Ahammad R (2012) Navigating mangrove resilience through the ecosystem based adaptation: lessons from Bangladesh. In: Macintosh DJ, Mahindapala R, Markopoulos M (eds) Sharing lessons on mangrove restoration. Mangroves for the Future and Gland/IUCN, Bangkok/Switzerland, pp 243–254

Nandy P, Islam MA (2010) Climate resilient coastal zone development in Bangladesh: participatory governance for common resources management. In: Ramanathan AI, Bhattcharya P, Dittmar T, Prashad MBK, Neupane BR (eds) Management and sustainable development of coastal zone environments. Capital Publishing Company, New Delhi, pp 58–72

Nandy P, Paul SP, Moula MG, Imam MF, Basak SR, Miah MAQ, Mannan MA (2003) Stakeholder analysis through participatory rural appraisal for land use and joint forest management in raised coastal areas. PRA Bulletin, Plantation Trial Unit Division, Bangladesh Forest Research Institute, p 58

Nandy P, Alam MJ, Haider MR (2004) Establishment of mangrove seed production area for *Sonneratia apetala*. J Trop Forest Sci 16(3):363–368

Nicholls RJ, Branson J (1998) Coastal resilience and planning for an uncertain future: an introduction. Geogr J 164(3):255–258

Nicholls RJ, Wong PP, Burkett VR, Codignotto JO, Hay JE, McLean RF, Ragoonaden S, Woodroffe CD (2007) Coastal systems and low-lying areas. In: Parry ML, Canziani OF, Palutikof JP, Van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, pp 315–356

Olsson P, Folke C, Berkes F (2004a) Adaptive co-management for building resilience in social-ecological systems. Environ Manage 34:75–90

Olsson P, Hahn T, Folke C (2004b) Social-ecological transformation for ecosystem management: the development of adaptive co-management of wetland landscapes in southern Sweden. Ecol Soc 9(4):2, www.ecologyandsociety.org/vol9/iss4/art2. Accessed 1 Oct 2012

Quinn CH, Huby D, Kiwasila H, Lovett JC (2007) Design principles and common pool resource management: an institutional approach to evaluating community management in semi-arid Tanzania. J Environ Manage 84:100–113

Rahman MH, Lund T, Bryceson I (2011) Salinity impacts on agro-biodiversity in three coastal, rural villages of Bangladesh. Ocean Coast Manage 54:455–468

Reid H, Alam M, Berger R, Cannon T, Huq S, Milligan A (2009) Community based adaptation to climate change: an overview. In: Ashley H, Kenton N, Milligan A (eds) Participatory learning and action. IIED, UK, p 60

Saroar M, Routray JK (2012) Climate awareness and adaptation efficacy for livelihood security against sea level rise in coastal Bangladesh. In: Scheffran J, Brzoska M, Brauch HG, Link PM, Schilling J (eds) Climate change, human security and violent conflict. Hexagon series on human and environmental security and peace, vol 8. Springer, Berlin, pp 575–594

Secretariat of the Convention on Biological Diversity (2009) Connecting biodiversity and climate change mitigation and adaptation: Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change. Technical Series No. 41, Montreal, p 126

Shaw R, Krishnamurthy R (2012) Coast and communities: the linkages. In: Shaw R, Phong Tran (eds) Community, environment and disaster risk management, vol 9. Emerald Group Publishing Limited, Bingly, pp 101–112

Sieghart LC, Ganapin D (2011) Pace of change: climate change and the empowerment of local communities. In: Filho WL (ed) The economic, social and political elements of climate change, climate change management. Springer, Berlin, pp 837–845

Sorwar M (2005) Impacts of sea level rise on the coastal zone of Bangladesh. Master Thesis, Lund University, Lund, p 45

Staden MV (2010) Communities, mitigation and adaptation. In: Staden MV, Musco F (eds) Local governments and climate change. Adv Glob Chang Res 39:17–76

Sterrett C (2011) Review of climate change adaptation practices in South Asia. Oxfam Research Reports, Climate Concern, Melbourne, p 100

Tompkins EL, Adger WN (2004) Does adaptive management of natural resources enhance resilience to climate change? Ecol Soc 9(2):10. http://www.ecologyandsociety.org/vol9/iss2/art10. Accessed 20 Dec 2012

Tompkins EL, Brown K, Few R (2008) Science based stakeholder engagement: Incorperating stakeholders preferences into coastal planning for climate change. Journal of Environmental Management 88:1580–1592

Tschakert P, Dietrich KA (2010) Anticipatory learning for climate change adaptation and resilience. Ecol Soc 15(2):11, http://www.ecologyandsociety.org/vol15/iss2/art11/. Accessed 20 Dec 2012

van Aalst MK, Cannon T, Burton I (2008) Community level adaptation to climate change: the potential role of participatory community risk assessment. Glob Environ Chang 18:165–179

van den Bergh J, Nijkamp P (1998) Economic aspects of global change impacts and response strategies in the coastal zone of the Netherlands. J Coast Conserv 2:161–168

Vellinga P, Klein RJT (1993) Climate change, sea level rise and integrated coastal zone management: an IPCC approach. Ocean Coast Manage 21:245–268

Vignola R, Locatelli B, Martinez C, Imbach P (2009) Ecosystem-based adaptation to climate change: what role for policy-makers, society and scientists? Mitig Adapt Strateg Glob Change 14:691–696

Walker BH, Holling CS, Carpenter SR, Kinzig AP (2004) Resilience, adaptability and transformability in social–ecological systems. Ecol Soc 9(2):5. [Online] URL: http://www.ecologyandsociety.org/vol9/iss2/art5/

Wever L, Glaser M, Gorris P, Ferrol-Schulte D (2012) Decentralization and participation in integrated coastal management: policy lessons from Brazil and Indonesia. Ocean Coast Manage 66:63–72

Wilbanks JT, Kates RW (1999) Global change in local places: how scale matters. Clim Chang 43:601–628

Chapter 16
Adaptation Technologies in Practice and Future Potentials in Bangladesh

M. Mokhlesur Rahman and Aminul Islam

Abstract Bangladesh, being one of the most climate change vulnerable countries of the world pioneered in testing and adopting various adaptation technologies and approaches in different geographical settings of the country. Institutional response to climate change threats is reflected by the preparation and submission of Bangladesh NAPA to UNFCCC in 2005 earlier than many other least developed countries. Apart from various local adaptation initiatives undertaken by communities and NGOs, government agencies along with other actors are also implementing a number of adaptation projects in the area of agriculture, aquaculture and water and disaster management in different climate sensitive areas of the country through involvement of vulnerable communities. Being a least developed country with high population, major thrusts are given in food production and a number of technologies are in practice in the agriculture sector in different geographical locations have specific climate related stressors that necessitate specific adaptation technologies and options. Some adaptation initiatives to address disaster events and some piloting are done in disaster prone areas of the country have good lessons need to be documented for wider dissemination. Although various climate change adaptation project/activities are ongoing, stock taking of adaptation technologies in practice in geographical locations has not done yet for analysis of their effectiveness and further improvements. This chapter has two objectives. First, it briefly describes different adaptation technologies currently in practice in different climate sensitive disaster prone areas of the country by different actors with focus on agriculture, aquaculture, water and disaster risk reduction subsectors. Second, it briefly touches upon the potential for further innovations and extension of adaptation technologies reaching the millions of poor vulnerable communities live in the frontline of climate change impacts in Bangladesh and beyond.

M.M. Rahman
Centre for Natural Resource Studies (CNRS), Dhaka, Bangladesh

A. Islam (✉)
United Nations Development Programme, Dhaka, Bangladesh
e-mail: aminul.islam@undp.org

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*, Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_16, © Springer Japan 2013

Keywords Adaptation actors • Adaptation technologies • Bangladesh • Climate change

16.1 Introduction

Like other countries, Bangladesh has been experiencing the impacts of climate change and climate variability on the production sectors the most. Bangladesh is particularly vulnerable to multiple disasters and climate change related shocks due to its location, high population density, high levels of poverty, higher dependence on climate sensitive production sectors, lack of awareness of climate risks, and unplanned urbanization coupled with poor infrastructure (Islam et al. 2010). Being highly sensitive to climate stimuli, the agriculture is the most affected sector in Bangladesh and therefore major adaptation technologies that are developed and practiced revolves around agriculture. Fisheries and aquaculture sub-sector though sensitive to and impacted by the effects of climate change and climate variability but is not well addressed as yet. Water is the basic determinant of agriculture and fisheries/aquaculture production systems and influences the production, the sector is still lagging behind largely due to problems associated with prioritizing the adaptation focus. Historically, due to its location, high level of poverty, week infrastructure and institutional capacity and high dependence of people on climate and disaster sensitive sectors (agriculture and fisheries), Bangladesh is a disaster prone country. Flooding, cyclones, drought and salinity are major disasters which are now being exacerbated by the recent phenomenon of climate change and climate variability IPCC (2007). Bangladesh has made some good progress in the area of adapting to climate change induced disasters which though need further impoverishment and extensions to wider communities live in climate induced disaster hotspots.

This paper discusses some of the key adaptation technologies so far designed and now in practice in agriculture, aquaculture and water and disaster risk reduction (DRR) sectors in Bangladesh. These technologies include both hardware and software as well as orgware systems. The paper also presents an analysis as to how these systems addressing the climate change induced impacts in an integrated way and touched upon the needs for further improvements and extension of adaptation technologies in Bangladesh.

16.2 An Overview of the Technology Options: Bangladesh Context

In Bangladesh adaptation technologies in practice may be defined in four categories such as (a) hardware, (b) software, (c) orgware and (d) indigenous knowledge and wisdom based adaptation technology. Hardware refers to so-called “hard” technologies such as capital goods and equipment and includes new irrigation or water management systems or coastal protective dikes. Software refers to the capacity and processes involved in the use of the technology and spans knowledge and skills, including aspects of awareness-raising, education and training (Clements et al. 2011). Adaptation methods and practices that may not normally be regarded as technologies, such as insurance schemes or crop rotation patterns, may also be characterized as software. A third distinction which is equally important to the understanding of technologies for adaptation and their implementation is the concept of orgware, which relates to the ownership and institutional arrangements of the community or organization where the technology will be used. Many adaptation technologies have been utilized for generations to cope with climate variability and improve livelihood resilience to socio-economic stresses could be defined as the fourth category of adaptation technology based on the indigenous knowledge and wisdom.

International political negotiations and academic discourse on climate change adaptation are increasingly happening in two parallel, if not clearly distinctive tracks: a "general adaptation track" focused broadly on adaptation to climate change and how it can be mainstreamed into development planning and policies; and a "technology track" focused specifically on reducing vulnerability to climate change by facilitating the transfer and diffusion of appropriate technologies for adaptation. This duality in the adaptation discourse is also reflected in the global financial architecture for adaptation, with some funds making a formal distinction between the funding of "adaptation" and funding of "technology transfer for adaptation". In this way, the UNFCCC Special Climate Change Fund includes two separate windows managed independently by the Global Environment Facility, one focused on adaptation and one on technology transfer (covering both mitigation and adaptation).

In many cases it is observed in practice that hardware are combined with software and orgware to strengthen the capacity and enhance resilience while considering the issue in design level adequately embedded in vulnerable communities in climate induced hazard exposed area and thereby ensure the acceptance and ownership necessary for their adaptation technology. Hardware involved in different sectors includes water resources and hydrology such as ponds, wells, reservoirs, rainwater harvesting, coastal zones dykes, seawalls, tidal barriers, breakwaters, vector control, vaccination, climate proofing of building and infrastructure and so on. Software adaptation technologies include farming practices, research on new crop varieties, increase water use efficiency and recycling, development planning in exposed areas, urban planning, knowledge and know-how and so on. However, orgware includes, building codes, early warning systems, insurance and, health and hygiene education, health legislation and standards.

16.3 Adaptation in Agriculture

Bangladesh is largely an agriculture dependent country and majority of rural people still make up a major share of their livelihoods from agriculture and related activities. The contribution of agriculture sector alone in the national economy in FY

2011–2012 was 19.29% (MoF 2012). Agriculture sector as a whole is again very sensitive to climate related stressors. Recent phenomena of rising temperature, prolonged drought, erratic rainfall, increased frequency and intensity of flooding and cyclones, increased salinity, intense severe cold spells with dense fogs are all manifestations of climate change and climate variability that have already started impacting upon the agriculture and other sectors in Bangladesh. The farming communities of Bangladesh although poor and dependent on subsidies, but are also enterprising as well. Bangladesh is having a vibrant civil society and NGO communities who often take up proactive measures to tackle any crisis arise out of either climate or non climate related stressors.

A good number of technologies are being practiced in the agricultural sector of Bangladesh over the last few years that seemed aimed at addressing the recent threats to farming systems posed due to climate change and climate variability. Although some of the agricultural technologies are fairly old in practice but are now appropriate under the changing climatic conditions as viable adaptation technologies. Bangladesh though a small country has distinct spatial variability in climate related perturbations thus a generic agricultural adaptation technology package does not fit in to the diverse eco-regions of the country.

In consistent with the spatial variability, adaptation technologies in agricultural sector vary by different geographical settings of the country depending on the typology of climate induced stressors, soil types, inundation patterns and farming practices. For example, coastal area of Bangladesh is exposed to multiplicity of climate stressors viz. increasing soil and water salinity, cyclones and storm surges, drainage congestion, and changes in coastal morphology (WB 2000) and adaptive agriculture thus need to be adjusted to such climate and non climate factors. Warner et al. (2012) reported that 99 % of the respondents (N = 360, four villages) in a coastal sub-district of southwestern Bangladesh experienced increased salinity in their crop fields and fish ponds which is further aggravated due to cyclones Sidr and Aila in 2007 and 2009 respectively. Recent studies on cyclone formation in the Bay of Bengal shows an increasing trend with 7.94 storms per year or once in every 6.54 weeks by 2050 (Chowdhury et al. 2012). Increased frequency of cyclonic storms coupled with sea level rise will further exacerbate the impacts on agricultural production systems in the coastal zone of Bangladesh. Among the coastal zone, there are high and low saline areas depending on the proximity to land to the sea. The coastal areas at the lower estuary (exposed to coasts) are relatively more exposed to cyclones, sea level rise and salinity intrusion than that of the interior coast and thus the adaptation technologies for the coastal agricultural systems also vary accordingly (PDO-ICZMP 2004).

Agricultural technologies to adapt to the impacts of changing climates are varying spatially by different climate change related hot spots of the country. Recognizing the spatial variability of climate induced threats to agriculture, Bangladesh NAPA (MoEF 2005) suggested priority actions to develop crop varieties that can sustain high salinity, floods and drought related stressors to face the new threats associated with climate change in different parts of the country. Despite having spatial variability of nature and extent of climate change related impacts, there are some technologies to adapt to certain climate stressors that better suit almost all over the country. For example, late variety of rain fed Amon rice (BR 22, BR 23, and BRRI dhan 46) better suits all over the country in response to late monsoon flooding (in August) and concomitant loss of either mature seedlings in seed beds or newly transplanted seedlings in the crop fields. There are other varieties of amon rice invented by Bangladesh Rice Research Institute (BRRI) viz. BRRI Dhan-51 and BRRI Dhan-52 now in practice, can tolerate inundation due to sudden intense rainfall based flooding even for a period of 15–20 days (CSISA 2012).

16.3.1 Agricultural Adaptation in Coastal Zone

The coastal zone in the lower estuary used to be known as the single cropped area. In the past, people used to grow only amon rice (rain fed monsoon rice) during monsoon season when salinity level goes down due to high precipitation. While during dry season/winter salinity shots up and most of the coastal lands remained fallow except in some low saline areas (usually around the Meghna estuary area) people used to grow various non rice crops (oil seeds, pulses, water melon). However, recent increase in salinity due to sea level rise, coastal flooding and storm surges have made it difficult for the farmers to grow crops even in amon season. In this backdrop, over the last few years, various donor supported projects, Department of Agriculture Extension (DAE) and NGOs have been supporting the farmers to adopt new varieties of rice and various other non-rice crops in the saline prone areas and achieved encouraging results and these are now being adopted by the farmers as climate resilient crop varieties appropriate for the coastal zone (Table 16.1).

The coastal zone of Bangladesh is increasingly being affected by higher soil and water salinity due to combination of factors viz. withdrawal of water from upstream rivers, shrimp farming holding saline water in ghers and recent phenomenon of sea level rise. Due to salinity problem in the dry season (winter), farmers cannot grow boro rice (winter rice) in the coastal zone. To address the issue, Bangladesh Rice Research Institute (BRRI) and Bangladesh Institute of Nuclear Agriculture (BINA) have developed varieties of boro rice (winter rice) that can be grown in moderate saline affected areas in the coasts with profitable yields (BRRI 2012). These varieties (BRRI Dhan-47 and BINA-8) are getting popularity among the farmers in the coastal areas (CSISA 2012; CNRS 2012a; UNDP 2012). In many areas coastal farmers are now growing two rice crops per year, one in the rabi or boro season (boro rice) and on kharif-2 or amon season (amon rice).

Beside saline tolerant rice varieties, encouraging results are obtained by cultivating various non rice crops (maize, oil seeds, bean, etc.) in the saline affected coastal lands of Bangladesh (Patuakhali and Satkhira districts) to cope with high salinity problem (CNRS 2012a). Table 16.2 shows the non rice crop varieties performed well in the saline prone coastal zone of Bangladesh.

Along with the above crops chili, soybean, bitter gourd, sweet gourd, ground nut and water melon are also found as suitable crops for the salinity affected areas in the coastal zone. Apart from vegetables, specie crops, oil seeds and pulses, fruit trees

Table 16.1 Climate resilient rice varieties that are currently being practiced in Bangladesh

Climate-tolerant rice varieties	Growing season	Climatic conditions	Growth duration (days)	Yields (t/ha)
BRRI Dhan-47	Boro	Saline tolerant	152	6.0
BRRI Dhan-55	Boro	Saline and cold tolerant	145	5.5
BINA-8	Boro	Saline tolerant	150	6.5
BRRI Dhan-28	Boro	Flash flood zone	140	5.0
BRRI Dhan-45	Boro	Flash flood zone	145	5.5
BR-10	Amon	Late variety	150	6.5
BR-22	Amon	Late variety	125–150	5.0
BR-23	Amon	Late variety	125–150	5.5
BRRI Dhan-46	Amon	Late variety	124–150	4.7
BRRI Dhan-40	Amon	Saline tolerant	145	4.5
BRRI dhan-41	Amon	Saline tolerant	148	4.5
BRRI Dhan-53	Amon	Saline tolerant	125	5.0
BRRI Dhan-54	Amon	Saline tolerant	135	5.5
BRRI Dhan-51	Amon	Water logged	140–145	4.0–4.5
BRRI Dhan-52	Amon	Water logged	140–145	4.0–4.5
BRRI Dhan-56	Amon	Drought tolerant	110	4.5
BRRI Dhan-57	Amon	Drought and early variety	105	4.0–4.5
BRRI Dhan-42	Aus	Drought tolerant	100	3.5
BRRI Dhan-43	Aus	Drought tolerant	100	3.5

Source: BRRI (2012)

Table 16.2 Proven saline resilient non rice crop varieties developed by BARI

Sl. no.	Name of crops	Variety of crops	Growing season	Yield recorded (ton/ha)	Remarks
01	Mungbean	BARI mug 08 (BM-08)	Rabi	0.77–1.44	Sowing date early December provided highest return
02	Maize	BARI hybrid bhutta-04	Rabi	7.6–10.73	Also used as fodder
03	Maize	BARI Khoibhutta	Rabi	8.58–11.50	Also used as fodder
04	Maize	BARI hybrid bhutta-3	Rabi	9.08	Also used as fodder
05	Mustard	BARI sharisa-11	Rabi	1.57	
06	Cowpea	BARI Cowpea	Rabi	1.177	Sowing date 15 January provided highest return
07	Tomato	BARI Tomato-03	Rabi	37.86	To be cultivated in raised bed with mulching

can well be grown in the coastal semi-saline areas as adaptation to climate change threats. Common fruit trees are in practice in the coastal zone include Jujube (Apple kul and BAU kul), Mango (Amropoli), guava, papaya in the homesteads as well as raised crop fields (CNRS 2012a; Rahman 2012; UNDP 2012). These trees have some saline resistance quality and can produce return within very short period. However, due to soil salinity, there is need for bring some changes in the crop farming technologies in the coastal areas.

16.3.2 Agricultural Adaptation in Early Flash Flood Affected Haor Basin

16.3.2.1 Early Flashflood Zone (Haor Basin): Short duration boro rice

A vast low lying deeply flooded northeastern haor basin of Bangladesh is unique in its hydrological regimes and land use. The whole area except the settlements remains under water in the monsoon season for 5/6 months leaving a narrow window of 5 months (dry season) when the farmers can only grow boro rice (winter rice). However, the rice crop is highly susceptible to damage caused due to flash floods in early monsoon just before harvesting. The haor region is located at the foothills of Meghalayan hills of India which is one of the highest rainfall zones in the world (Cherapunjee, India). Analyzing the last 100 years rainfall data for the months of March and April in Cherapunjee, reveals that the rainfall has increased from 150 to 250 mm which increases the risk of flashfloods and so the risk of damage of boro rice in the plains of Bangladesh. The popular variety of boro rice is BRRI dhan 29 which gives highest yields (around 7.5tons/ha–dry weight) but this variety needs the longest cultivation period (around 165 days). Other varieties developed by BRRI dhan 45 and BRRI dhan 28 though produce slightly lower yields (less than 7.5 tons/ha) compare to BRRI dhan 29, but these varieties have shorter cultivation period (around 145 days) thus can save 3 weeks which is sufficient to get the rice harvested before the visit of flashfloods (Table 16.3). These varieties are now being disseminated by the NGOs and DAE among the farmers in haor basin as adaptation to flashflood hazard which is now more intense and visiting earlier than before due to recent phenomenon of high climate variability (CNRS 2011a).

16.3.2.2 Early Flashflood Zone (Haor Baisn): Kanda Farming

In the haor, there are large patches of state owned raised lands (khas land) along the edges of wetlands locally called “kanda” which were in the past remained covered by swamp forests and reed lands bur are cleared over time. Kanda lands remain fallow over years due to its harder soil, covered with shrubs and difficult to irrigate (CNRS 2012b). Recently conducted adaptive research on kanda farming revealed that both rice and non rice can be profitably cultivated in kanda lands. Last 6 years’ research developed technology packages for kanda farming which is not only profitable but also climate resilient (CNRS 2012b). As the kanda lands are raised compared to the traditional boro (crop) lands in the haor basin, flood water

Table 16.3 Adaptive crop demonstration results in the flash flood affected Haor areas of Bangladesh (2009–2010)

Crop name	Production (t/ha)	Input cost (US$/ha)	Output (US$/ha)	Profit (US$/ha)	Growth period (days)	Flashflood affected[a] (Yes/No)
1. Wheat	3.0	501	858	357	110	No
2. Potato	23.2	2,463	5,953	3,491	82	No
3. Mustard	1.2	599	1,064	465	79	No
4. Garlic	10.8	1,732	4,933	3,201	108	No
5. Tomato	23.8	1,264	4,383	3,119	119	No
6. Garden pea	7.7	1,282	4,424	3,142	96	No
7. Soybean	2.1	781	1,473	692	92	No
8. Sweet gourd	50.2	1,410	4,304	2,894	113	No
9. France bean	9.7	1,743	2,493	750	83	No
10. Bitter gourd	25.1	4,061	8,229	4,168	125	No
11. Country bean	12.9	1,919	3,682	1,764	101	No
12. Radish	27.4	2,323	3,128	805	84	No
13. Brinjal	15.9	3,062	3,860	798	135	No
14. Mung bean	1.9	987	1,938	951	64	No
15. Bottle gourd	19.2	146	1,370	1,224	134	No
16. Yard long bean	4.1	444	1,161	717	55–87	No
17. Ladies finger	1.3	216	517	301	111	No
18. Stem amaranth	8.9	870	2,024	1,153	66	No
19. Indian spinach	46.3	2,904	7,941	5,037	35–95	No
20. Bati shak	13.3	1,493	2,659	1,167	40–78	No
21. Red Amaranth	10.4	1,280	1,491	212	30–65	No
22. China shak	10.5	1,285	1,946	662	35–85	No
23. Rice (BR 45)	5.9	611	840	229	136	No
24. Rice (BR 29)	**6.4**	**611**	**911**	**300**	**163**	**Yes**

Source: CNRS (2011a)

[a]Crops have less than 145 days of growth period are resilient to CC impacts as these can be harvested before the visit of flash floods in mid to late April

receded around 3 weeks earlier from kanda than the boro lands and again gets flooded around 3 weeks later than the boro lands. Thus farmers get around 6 week additional time for farming in kanda lands and this allow double cropping. As first round crops, farmers cultivate potato or mustard or wheat or vegetables, chili in November and after harvesting the first crop in February, the lands again planted with sesame or okra or vegetables or jute. Kanda farming system is adopted by the people in the haor basin as adaptive cropping system due to avoidance of flash-floods, double cropping, high profitability and crop diversity. The results also show that crop varieties that have growth period of less than 145 days can be safely harvested in the single cropped haor basins viz. BR 45 and BR 28. It indicates that rice mono culture in the haor basin with the long duration high yielding boro variety (BRRI Dhan 29) is highly susceptible to climate related hazards. By contrast, cultivation of short duration non rice crops (less than 100 days growth period) viz. amaranth, potato, mustard, beans, spinach offer opportunities for double cropping and thus profits can be maximized (CNRS 2012b).

16.3.3 Agricultural Adaptation in Southwestern Water Logged Area

16.3.3.1 Water Logged Area: Agriculture on Floating Mats

For example, there are some pockets of areas in the southwestern coastal districts where drainage congestions caused permanent inundation of lands that have made unsuitable for crop farming. To make use of this congested water, local communities have been practicing an indigenous method of vegetables farming on floating mats locally called "baira" (hydroponics). Floating mats are made up on banana rafts upon which layers of soil and decomposed water hyacinth with some soil materials are laid at a width that can support growth of crops/plants. This practice of crop cultivation on floating mats was first invented by the farmers in the water logged areas of southwest (Madaripur and Gopalgonj districts). The baira farming technology has been taken up by many communities in different parts of the country as a viable option for farming in water logged areas. This technology is now being widely used as adaptation to climate change impacts.

16.3.3.2 Late Varieties of Amon Rice: Suitable Option for Adapting Intense Monsoon Rainfall

Erratic rainfall has been the recent features of rainfall pattern as the manifestation of climate variability. Intense continuous heavy rainfall over the first 2 weeks of August 2012 damaged most of the amon rice seedbeds prior to transplantation in the southwestern sub-district Shaymnagar of Satkhira district that delayed transplantation period for more than one and half months. In that context, some farmers transplanted seedlings of BR 22, BR 23, BRRI Dhan 46, and found satisfactory production – over 5 tons/ha (CNRS 2012a). In the face of changing climates with higher uncertainty of rainfall, late varieties of amon rice have been the viable adaptation option for such climate stressors.

16.3.4 Agricultural Adaptation in Northwestern Drought Prone Area

16.3.4.1 AWD Irrigation Method in Drought Prone Area

Alternative wet and dry (AWD) method of irrigation saves water in boro rice cultivation by supplying water to the rice plant as per requirement, instead of continuously keeping water in rice plots. The plots are once irrigated and then water supply is discontinued and dried and again irrigated. To determine the irrigation time usually a PVC watch pipe (water measuring pipe) having 30.0 cm length and

10.0 cm diameter is set at a depth of 20.0 cm bottom and 10.0 cm is keep up of the surface soil at three to five representative places (one in the middle and another four at corner area). The lower 20.0 cm of the watch pipe usually have 5.0 mm diameter hole at a distance of 10.0 mm and the upper 10.0 cm of watch pipe is blind or without any hole. After sowing the seedlings of rice, irrigation is done at 5.0 cm of level of the watch pipe above surface soil and this condition is maintained 2 weeks by supplying water for development of tiller of the plants and to control uprising of weeds in the rice plots. After this period, irrigation is discontinued and the plots are dried and when the water level goes beyond 15.0–20.0 cm level of the watch pipe, irrigation is again done at a height 2.0–4.0 cm level of the watch pipe above the surface soil. In this way irrigation is continued till the flowering of the rice. From beginning of flowering of the rice again irrigation is done at 5.0 cm level of the watch pipe from the surface soil and is continued for 2 weeks. Prior to 2 weeks of rice harvesting irrigation is discontinued. The water level of the watch pipe can be easily measured with a simple scale. Through AWD method farmers can save 15-30% water and thus irrigation costs with no impact on yields (Toung 2007; Kulkarni 2011). CNRS demonstrated this technology in Pabna area through its GIZ assisted wetland biodiversity rehabilitation project (WBRP) and documented savings of irrigation costs of BDT 5,467/ha with an increased in yields by 13.07% compared to control plots (CNRS 2011b).

16.3.4.2 Ground Nut Cultivation in Sandy Soil

In charlands (riverine sand bars) and flash flood areas where flood-borne silt/sand carpeting on croplands made it unsuitable for rice and other cereal crops to grow including areas where water stress is higher due to drought, ground nut can be a viable option for such areas. Farmers in charland areas of Ganges, Brahmaputra and Meghna Rivers have been cultivating ground nuts over years where high sand deposition degraded the lands. Under the current climate related stressors traditional farming systems in more and more areas of the country being affected due to water stress, drought and sedimentation or sand carpeting where ground nut cultivation has high potential to adjust to such climate related perturbations. Recently, increased crop land areas in the northeastern haor areas being degraded due to sand carpeting associated with increased frequency and intensity of flash flood-borne sand depositions. Some farmers in such areas of haor basin have already started ground nut cultivation with support from the DAE and NGOs as an adaptation option (CNRS 2012b).

16.3.5 Technological Innovations in Agriculture

Apart from the selection and cultivation of various climate stress tolerant crop and rice varieties in different climate sensitive geographical areas of the country, farmers also adopted technological innovations in response to the site specific climate induced stressors. To this end, cultivation techniques adopted in the coastal saline zone vary from the one adopted in flashflood affected haor areas. While a technology that better suits the haor basin does not work in drought prone barind areas. Apart from climate zone-wise adaptation technologies, some special technologies have been developed to address local problems mostly by the communities themselves.

Common technologies adopted in the farming systems in the face of climate change threats include raised bed farming, mulching, water storage in fields, ditch and dyke model, kanda farming, agro forestry, drip irrigation, solar irrigation systems, etc. some of the common agricultural adaptation technologies are presented in Table 16.4.

Table 16.4 Some common agricultural adaptation technologies in practice in Bangladesh

Technologies	Description
Raised bed	This technology is used for vegetables and fruit trees that decrease the salinity level and increase the production ***Spatial Suitability***: Coastal saline zone and drought prone areas
Mulching	Mulching helps to increase the soil moisture level and decrease the salinity of soil ***Spatial Suitability***: Coastal saline zone and drought prone areas
Water storage in crop fields	Excavate small ponds/ditches at one corner of the crop field or canals along the edges to store rainwater. These are effective technologies for the dry season when the salinity increases in soil and water in coastal lands ***Spatial Suitability***: Coastal and drought prone areas
Ditch and dyke method of farming	Plain land is converted to ditch and dyke where fish is farmed in ditches while vegetables, orchard, trees are grown on dykes. This system facilitates bringing the fallow saline land under productive use. For the first couple of years, salinity concentration in the soil affect the yields of corps and fish to some extent but after passing two successive monsoons, salinity level goes down and farmers can get good yields and returns afterwards ***Spatial Suitability***: Coastal saline prone areas
Mound plantation	Plantation of trees on raised mounds in the coastal saline lands has very high potential for replication. UNDP/GEF project on “coastal adaptation” popularizing this technology in the coastal area of Bangladesh engaging local communities. This technology has high potential to address slow on set climate change impacts like sea level rise and salinity intrusion ***Spatial Suitability***: Coastal saline affected area
Agro-forestry	Due to recent phenomenon of unpredictable climate variability (rainfall, drought, temperature) farmers have changed farming pattern to adjust to changing climatic conditions (drought, water stress). In some places people have adopted agro forestry technology (fruit trees like mango, jujube, litchi and guava with cereal crops) in place of monoculture of rice or other cereal crops which are more sensitive to climate stimuli. This practice is seen in the southwest and northwestern parts of the country as an adaptation option ***Spatial Suitability***: Drought prone areas

(continued)

Table 16.4 (continued)

Technologies	Description
Drip irrigation	Areas prone to intense prolonged drought in the summer and monsoon and experience crop loss, adoption of drip irrigation system enhances water efficiency and enables maximum irrigation with minimum water available ***Spatial Suitability***: Drought prone areas
Non-traditional crop varieties	Soybean and sunflower are profitable in the haor and coastal areas. In the coastal area organic manure is scarce due to massive shrimp farming; soybean cake (after extracting oil) can be applied as manure in crop fields/homestead gardens. Application of organic manure can enrich soil quality and desalinize the soil and thereby regain the soil productivity Floriculture in drought prone southwestern areas (greater Jessore area) has advantage that these need less watering and can tolerate higher weather stresses than that of traditional cereal crops. The flower also has good market demand and thus the participating farmers could make more profit in floriculture than farming cereal crops ***Spatial Suitability***: Coastal, haor and drought prone areas

16.4 Aquaculture Based Adaptation

Like agriculture, aquaculture system is also vulnerable to climate change impacts. Erratic rainfall (intense heavy rainfall, delayed monsoon rains) and consequent flooding, cyclones and storm surges, high tides, coastal flooding, increased salinity, intense early flash floods, prolonged drought, higher temperature are all manifestations of climate change and climate variability have adverse impacts on aquaculture in fish ponds and shrimp ghers. Impacts of climate change related stressors on aquaculture systems vary by locations and types of climate stressors. For example, the aquaculture systems in the northeastern haor basin are affected mainly due to early flashfloods that caused inundation of fish ponds and sand depositions in pond bottom. While in the northwestern drought prone areas, aquaculture system is being affected by prolonged drought that dry out ponds earlier than before and thus shortening the culture period with resultant decrease in fish production. Although, high temperature can expedite growth of fish but shorter culture period reduced the yield per production cyclone. The aquaculture systems in the coastal zone is affected by multiplicity of climate related stressors as the area is exposed to some additional threats viz. cyclones and storm surges, salinity intrusion and high tides (MoEF 2005). Increased intensity of frequency of cyclones and storm surges will likely to result in increased coastal flooding coupled with inundation due to sea level rise damage coastal fish ponds and shrimp ghers including capture fisheries habitats such as coastal wetlands and mangroves swamps (Cruz et al. 2007). Climate change will affect the aquaculture including both fish and shrimp farming in various ways (De Silva and Soto 2009). It is expected and already farmers started to experience, higher temperatures, prolonged drought, erratic rainfall, cyclone and higher salinity posing direct impacts on fish and shrimp aquaculture in inland as well as in coastal areas of Bangladesh. People also experience indirect impacts of climate change,

Table 16.5 Climate related stressors affected aquaculture in south-western coast in last 5 years

Climate change induced threats	Impacts on aquaculture
2007, November: super cyclone Sidr	Damaged over 80 % fish and shrimp *ghers* and disrupted fishing operations
2008, September: abnormally high tide and coastal flooding	Breached and overtopped coastal dykes and damaged many fish./shrimp ponds/*ghers*
2009, May: cyclone Aila with high surge water	Damaged 80–100 % fish/shrimp ponds/*ghers* and affected fishing operations
2009, August: intense rain-based flooding	Flooded many fish/shrimp ponds/*ghers*
2009, October: post monsoon drought	Heat stressed affected shrimps
2010, April–June: pre monsoon drought	High temperature affected pond/*gher* ecology, heat stress affected shrimp growth
2011, August: intense heavy rain-based flooding for about 2 weeks	Over 80 % ponds/*ghers* flooded and all fish and shrimps died due to sudden fluctuations of pond/*gher* ecology
2012, January: severe cold spell with dense fogs (around 10 days)	Affected *gher* ecology, increase diseases of fish/shrimps, inhibit fish/shrimp growths, high mortality, loss of dyke crops

Source: CNRS (2012c)

particularly the fish traders business is affected due high temperature and drought cause water stress, traders need more ice for fish preservation and transportation, escaping of fish and shrimp from ponds due to flooding and cyclones resulted in low landings and poor trades and return on investment (CNRS 2011c).

Recent experience of aquaculture and shrimp gher farmers in the coastal districts of Satkhira give testimony of climate change impacts on aquaculture systems that necessitates urgent measures aquaculture adaptation to climate change induced threats (Table 16.5). This data shows that cyclone induced flooding and saline water inundation of ponds and ghers, intense rain-based flooding of ponds/ghers, prolonged drought during pre and post monsoon months and severe cold spells affected fish ponds and shrimp ghers at varying extents at different times of the culture periods. These climate change-induced stressors affected the aquaculture systems eight times over a period of 5 years is an indication of frequent and repeated impacts of climate change in different seasons of the year which the farmers are not ready with.

Although the impacts of climate change on fisheries and aquaculture system happened to be high in Bangladesh due to higher exposure to climate change related shocks, effective studies to assess impacts and adaptation measures to adjust are yet to be formulated. However, Bangladesh NAPA (National Adaptation Programme of Action) suggested two priority adaptation actions for aquaculture in two areas of the country have higher exposure to climate related stressors (MoEF 2005). One such area is the salinity affected coastal zone where NAPA emphasized on introduction of saline tolerant fish species in aquaculture systems. The haor basin is the second site where frequent flash flooding inundates fish ponds and croplands and NAPA suggested net fencing of fish ponds and introduction of cage and pen aquaculture in flooded lands as urgent adaptation measures (Table 16.6).

Table 16.6 Bangladesh NAPA suggested priority adaptation actions for aquaculture

Climate sensitive areas for aquaculture	NAPA suggested aquaculture adaptation to climate change impacts
Flash flooded affected haor basin the northeast	• Net fencing of ponds to prevent escaping of fishes from culture ponds • Promote pen and cage culture of fish in floodplain areas during flood season with as an alternate option for fish culture
Salinity affected coastal zone in the south	• Develop technology for salt tolerant fish species for coastal aquaculture • Promoting developed aquaculture in the priority coastal zone • Develop linkages with weather forecasting agencies through networking • Helping the coastal aqua-farmers, particularly the shrimp farmers

Although NAPA follow up project on fisheries and aquaculture projects is yet to be launched, communities under different development projects have started adaptive aquaculture practices in different parts of the country including the coastal zone and haor basin.

Crab fattening: Coastal zone become increasingly risky in carrying out profitable farming of crops as well as fish and shrimps due to hostility of climate factors. Two weather extremes like prolonged drought and intense heavy rainfall underpinned by increasing salinity makes it difficult for the farmers to adjust their farming systems (fish, shrimp and rice farming) in high saline coastal areas in the southwestern Bangladesh (especially Satkhira and Khulna districts). More than a decade back, with support from NGOs and DoF, some farmers started crab fattening in small ponds/ditches where water salinity is higher. These ponds are well protected by net/bamboo fences so that the stocked crabs cannot walk out of the enclosures. They use to collect soft shell crabs from the Sundarbans mangrove forests or from local landing centers and stock those in mini ponds and rear (feeding) for 2–3 weeks until the crabs attain berried condition with the appearance of gonads. These berried crabs are harvested and sold at local markets. In 2 month time 3–4 fattening cycles can be completed.

Dry season is the best time for crab fattening when the salinity level remains higher. The advantage of crab fattening is that it takes only 2–3 weeks time to complete a production cycle and thus chances of being affected by climate factors are less and the farmers get a quick return. Other advantage of crab fattening is that the women folk can carry out the fattening activities as this is done in small homestead based ponds and thus it is easy for the women folk to take care of the system. In high saline area crab fattening is now appearing as a good livelihood adaptation for the poor to climate change induced threats (Ferdoushi and Xiang-Guo 2010).

Mono Sex Tilapia farming: In the coastal areas some people have started culture of mono sex tilapia in small ponds. Tilapia can tolerate mild salinity and over years it proves that they grow well in coastal semi-saline waters. Recent introduction of mono sex tilapia farming has gained popularity among the fish farmers due to rapid growth of this variety and for its short culture period that ranged from 3 to 4 months. A farmer can get three to four crops per year. Although the stocking material (fry) of this variety is not easily available all over the country, private hatcheries are coming up to meet the demands of the farmers and started production of fry in mass scale. UNDP/GEF assisted coastal adaptation project and USAID assisted Feed the Future (FTF) Aquaculture projects has been supporting poor households in vulnerable coastal districts to practice mono sex tilapia farming in small homestead ponds by engaging the women folks (Rahman and Siddque 2012). Cultivation of this fast-growing and saline tolerant variety of fish has high potential to sustain livelihoods of the coastal communities vulnerable to climate change impacts. This technology is a viable option for adaptation to climate change impacts not only in coastal but also in other areas affected by climate change stressors like drought and floods.

Fish Culture with Repeated stocking and repeated harvesting: Carp poly culture in ponds has been a traditional fish farming practice in rural Bangladesh where different species of Indian major carps and Chinese carps are stocked based on their feeding niche in layers of ponds water. In the past, ponds were stocked with fingerlings in May–June and harvested later at the end of the year (March–April) and then again restocked for another year and so on. However, modern technology now being practiced by many farmers—they practice repeated stocking and repeated harvesting in ponds almost round the year. This way, production and profit both have proven to be maximized. In this system, farmers at least gain a partial benefit even if his/her pond is affected by disaster (cyclone, flooding) or disease epidemics. Under the current climate change scenario, pond fish culture is also become vulnerable to threats associated with drought, intense heavy rainfall based flooding, high salinity (in coastal zone), cyclones and higher disease susceptibility. However, higher temperature facilitates fish growth and farmers can adjust stocking that corresponds with time of the year when temperature rises and remain so for months together with moderate rainfall to realize benefits of climate change. In high climate risk areas fish (carp) poly culture adopting "repeated stocking and repeated harvesting" system has been a viable adaptation technology which many farmers are already practicing with support from the Department of Fisheries (DoF) and NGOs.

Cage aquaculture: Cage aquaculture is a technology for raising fish in net enclosure in many countries including Bangladesh. However, the experience in Bangladesh s not very promising due to various factors viz. quality fish seed, fish feed, water pollution, care taking and poaching. However, the Bangladesh Fisheries Research Institute (BFRI) demonstrated high profitability through Pangus (Thai cat fish) rearing in river cages in one of the coastal districts (Chanpdur) of Bangladesh. Pangus rearing in cages is also a short cycled crop and thus have opportunities to avoid risks of climate related stressors compared to year long fish culture in ponds. This technology can be transferred to other areas where similar situation exists and can be a viable adaptation option for the fish farmers. In addition, teachers of Chittagong and Khulna universities demonstrated profitable mud crab fattening practice in bamboo split cages a decade back can also be disseminated among the coastal vulnerable households as means of livelihood adaptation in the face of climate change threats.

Shrimp farming: Salt water shrimp farming (*bagda—Paneus monodon*) started in the coastal zone of Bangladesh since early 1980s (Swapan and Gavin 2011). People in the southwestern district of Satkhira and in the southeastern district of Cox's Bazaar first started shrimp farming in shallow modified rice paddies locally called *ghers*. Short culture cycle with high profitability due to increased demands in export markets soon encouraged many farmers and investors/private entrepreneurs to jumped in to shrimp farming business and by mid 1990s shrimp farming expanded to other southwestern coastal districts. In places where water salinity level is very high in the dry season, people farm *bagda* (salt water shrimp) and in places where salinity is comparatively low, *golda* (*Macrobrachium rogenbergii*—giant freshwater prawn) mixed with white fish mainly carps and tilapia has been in practice. In high saline *bagda* farming areas too, people started farming *golda* mixed with white fish in monsoon months (low salinity) alternatively after *bagda* in the dry season (high salinity). In some places, farmers also cultivate rice (mainly amon rice) in their *golda* farms and get an additional crop in variable quantities. Due to sea level rise and increasing events of high tides with higher water levels, many new areas in the coastal zone being transformed from low saline to medium and high saline areas compared to the past. Rice farming in these newly saline-infested areas is getting difficult and non profitable and thus shrimp farming is emerging as a viable option to adapt to local environmental changes.

Sea bass farming: Sea bass (*Lates calcarifer*) locally called *vetki* or *coral* is a brackish water species found in the coastal zone of Bangladesh in large quantities. This species comes from capture sources although it has high culture potential and has very high commercial value both in country and export markets. In some areas of southwestern (viz. Satkhira district), a few farmers recently started sea bass farming in ponds/*ghers* mixed with white fish mainly tilapia. Sea bass has high potential in aquaculture in coastal saline prone areas. However, sea bass farming technology is yet to be standardized through field trials and adaptive research before it is to be put on for expansion in mass scale as adaptation technology to climate change impacts in the saline prone coastal zone of Bangladesh.

16.4.1 Aquaculture Technologies in Climate Change Affected Southwestern Bangladesh

Worldfish is implementing a 5-year long project under the feed the future FtF aquaculture program of USAID aiming at increasing fish and shrimp productions in the southwestern districts of Bangladesh since 2012. The project currently demonstrating 12 different aquaculture technologies encompassing wide range of aquaculture practices viz. improved culture techniques of commercial species like shrimps, prawns, carps, tilapia, pangus and experimental production techniques of non-traditional species like mola, singh, magur, koi in ponds (Rahman and Siddque 2012). Of these technologies, 7 are being demonstrated in high saline prone Khulna area, 7 in low saline prone Barisal areas, 11 in mild to no saline prone Jessore and Faridpur areas (Table 16.7).

Table 16.7 FtF aquaculture technologies for the southwestern coastal zone

Aquaculture technologies	Outlines of technologies	Implementation sites/ locations
1. Closed systems *bagda* farming	• Improved semi-intensive culture systems—ghers stocked @ 25,000–30,000/acre (without aeration) and 40,000–60,000/acre (with aeration) • Ready feeds applied to ghers targeted to shrimp, regular monitoring is done	Khulna (coastal saline areas)
2. Modified Traditional Technology (MTT) for Bagda farming	• Rear bagda PL in nursery for 21–30 days and then stock in ghers @ 4,000–5,000 bagda/acre for grow out • After bagda, restocked the ghers with golda @ 4,000–5,000/acre • Farmers also stock some white fish in it @ 150–200/acre • Ready feed is applied in most of the ghers	Khulna (coastal saline areas)
3. Golda (giant freshwater prawn) mono farming	• Ghers/ponds stocked with 5,000–6,000 PL/acre • Ready feeds applied from commercials sources	Khulna (coastal saline areas)
4. Mono sex Tilapia farming in ponds	• Ponds stocked with 200 fry/decimal (shallow ponds) and @ 300–400 fry/decimal in deeper ponds • Floating ready feed applied @ initially 5–7 % and then @ 3 % body wt	Khulna, Jessore Barisal
5. Pangas farming	• Ponds stocked with 200–250 fry/decimal • Floating ready feed applied	Khulna (coastal saline areas)
6. Carp ploy culture	• Ponds stocked with 40 large fingerlings/decimal (7 fingerlings make a kg) • Some farmers also stock tilapia and golda in it	Khulna, Jessore, Barisal
7. Cage culture in river, lakes, running khals	• Cages stocked with 1,000–1,500 large size fingerlings/cage (30–35 g each) • Feed applied 2/3 times daily (ready feed)	One place in Jessore and six places in Barisal areas
8. Carp brood development	• Maintaining stocking density of 12 kg/decimal • Brood from sources used for induced breeding sources from Govt. Farm, Natore, Bogra and WF listed hatcheries • 45 % Rui, 30 % Silver carp, 10 % Catla, 10 % Mrigal and 5 % Grass carp • 2–3 % feed of body wt with 25 % protein • 200 g Urea, 100 g TSP and 2 kg cow dung/decimal/2 months	Jessore , Faridpur and Barisal

(continued)

Table 16.7 (continued)

Aquaculture technologies	Outlines of technologies	Implementation sites/ locations
9. Carp seed development	• Spawn collected from natural sources (Halda, Padma and Jamuna Rivers) including Danida/WFC sources, spawn rearing for future broods, some brood nurseries developed for demonstration purposes • Feed applied for two to three times with oil cake and rice bran @ 50:50	Jessore, Faridpur and Barisal
10. Mono sex tilapia seed development	• Brood supplied from BFRI and from Malaysia to hatcheries received training from AIT, Thailand, seeds are given to Worldfish listed hatchery owners, DoF and BFRI farms • Rearing at very low density to use as broods in the next season	Khulna, Jessore and Barisal
11. Mola with Carps	• Mola with carps, brood collected from different sources and distributed to farmers and stocked @ 1–2 kg per decimal stocked @ 100 mol/decimal in carp poly culture for grow out • Only rise barn and kitchen extracts are applied as feed • 200 g urea, 100 g super phosphate and 2 kg cow dung per decimal/month	Jessore and Barisal
12. Shing, Magur and Koi demo	• Demonstration the technology, stocked @ Shing 500–600/decimal, Magur 300–400/decimal, Koi 300–400/decimal • Targeted ready feeds are used with no extra fertilization of ponds	Jessore areas

Source: Rahman and Siddique (2012)

16.5 Water Related Adaptation

Water stress will be one of the major threats to human society in the age of climate change with differentiated shocks over different seasons. Bangladesh NAPA (MoEF 2005) focused on water issues by mentioning that water related impacts would be one of the most critical threats to Bangladesh due to climate change with higher impacts in the coastal, riverine and drought prone areas. It is expected that at times there would be too less water to support functioning of ecosystems and landscape-based production and extraction sectors while in other seasons and other areas (even at the same time) of the year, people suffer from excessive water that would damage the livelihood assets including availability of drinking water. The coastal zone of Bangladesh is seriously affected by salinity intrusion which is now being intensified due to sea level rise coupled with reducing freshwater flows from rivers upstream caused mainly due to unilateral withdrawal of Ganges River water by India through Frakka Barrage since 1975 (Mirza 1997). Water related adaptation to climate change threats has made progress in the coastal areas of Bangladesh particularly focusing on drinking water availability and adopted various measures like rainwater harvesting, pond sand filter, piped water systems, and drinking water from some dedicated ponds.

Rain water harvesting: Rainwater harvesting has been a common practice in the coastal zone where salinity concentration in rivers, canals, ponds and ground water is higher particularly during dry season. This practice is also adopted in areas where arsenic concentration in ground water is high. People in high saline coastal areas collect rainwater during monsoon and store it in large earthen pots, plastic tanks, and concrete tanks for use in post monsoon period. This practice is largely done on individual basis as well as collectively where some households jointly collect, store and share rainwater afterwards. Quantity of rain water harvested depends on the ability of the households to arrange numbers and size of water storing pots. This practice is popular in the exposed coastal zone where salinity is higher in the Southwestern districts mainly in Satkhira, Khulna and Bagerhat.

Pond sand filter: In the high saline coastal zone of Bangladesh especially in the districts of Satkhira, Khulna, Bagerhat and some parts of Barguna people suffer from the scarcity of drinking water particularly in the dry season when salinity level goes higher both in surface and sub-surface water sources. Under the current phenomenon of climate change, this problem is further aggravated particularly after the two cyclones in 2007 and 2009. Pond Sand Filter (PSF) is a technology that demonstrated by DPHE/UNICEF with NGOs in the coastal districts since 1985 (Ferdoushi and Bolkland 2000). Communities in such places collect drinking and cooking waters from these facilities. This technology is now proven and a viable adaptation option in the high saline coastal areas to meet the demand for sweet water for drinking and cooking purposes.

Desalinization for drinking water: In some of the saline prone coastal areas, desalinization of available saline water can be a viable option for making availability of drinking water at household level. UNDP through its CDMP-II project has supported many poorer communities in the southwestern districts to install desalinization devices. These devices desalinize the saline water from nearby ponds or canals and make the water suitable for drinking and cooking. However, this technology is costly and a villager alone cannot afford to have this device due to financial incapability.

Piped watering systems: Recently, piped water system is demonstrated in a few places in the high saline coastal zone where underground water in some pocket areas are found sweet and drinkable but are difficult to access by many households due to poor communication systems as there are networks of canals in the coast with inadequate bridges and culvert to cross. In such areas NGOs and UNDP through CDMP-II project initiated solar powered piped water distribution system from the sources of sweet water to the villagers. This technology is appropriate for the coastal zone to reduce peoples suffering from the scarcity of drinking and cooking water and can save time for women and men spend in fetching water from distant sources otherwise can do productive or cost saving works for the ease of the households' livelihood security.

16.6 Disaster Related Adaptation

Historically, Bangladesh is a disaster prone country and every year it experiences one or more climate induced disasters in the form of flooding, cyclones, drought that affect lives, livelihood assets in many parts of the country (MoEF 2005). Among others flooding both early flashfloods and monsoon flooding have been a normal phenomenon and every year 20–25 % of the country is inundated by some form of flooding. Flooding intensity varies by year and has estimated that 37 %, 43 %, 52 % and 60 % of the country gets inundated with floods of return periods of 10, 20, 50 and 100 respectively (MPO 1986). Recent phenomenon of climate change and climate variability further intensifying the already existing climate related hazards like river flooding, coastal flooding, erosion, cyclones and storm surges resulted in increasing loss of lives, assets, infrastructure and production sectors. Cyclonic storms and flooding killed more than 4.6 hundred thousand and 41 thousand peoples respectively and affected nearly 45 and 356 million peoples respectively during 1970–1998 (MoEF 2005). The north eastern deeply flooded haor basin is susceptible to monsoon flooding for around 6 months of the year. High winds in monsoon cause strong waves in haor area that erodes village mounds at varying degrees each year. Climate change induced higher flooding and storms cause more intense winds and waves and more and more villages are now at risks of being eroded. Different models of village protection mounds (CC blocks, RCC retaining wall, CC blocks, brick wall and bamboo grass-mud-fencing local methods) have been demonstrated by different NGOs, projects and communities in the area to save the villages from erosion. To protect houses from flooding, making house on raised plinth has been practiced in the riverine and coastal char lands. The CDMP-II has taken up a recent initiative to raise the entire village rather houses as test case in southwestern districts of Khulna and Satkhira. In the coastal area, the fishing communities face problems of boat capsizing due to increased frequency and intensity of cyclones, rough sea weather conditions and sea level rise. Technology to strengthening boat to withstand shocks is tested in Noakhali areas has high potential for replication (Rahim 2008). Some of the key adaptation technologies to address disaster issues are presented in the following section.

16.6.1 Village Protection from Erosion in Haor Basin

During monsoon the flooded haor basin looks like a vast inland sea. In the event of high winds, strong waves form in haor during monsoon that erodes the villages that directly exposed to wave actions. As this has been an old problem, villagers used to take up various measures to protect settlements. In this climate change era, villages of deeply flooded area are exposed to severe erosions. Several technologies are tested to protect village mounds from erosion. Raising RCC retaining wall and CC blocks were tested under a donor supported project to protect some wave affected villages in around a decade back in the haor areas. Although retaining wall worked well but the technology is very costly. Later in 2009–2010 only brick wall (no cement and non re-enforcement) against wave action on exposed sides of the villages resulted well and the technology is cheaper than RCC retaining wall and CC blocks. Compared to concrete retaining wall and CC blocks, this simple brick made retaining wall is cheaper and easy to construct. The brick made retaining wall can be a viable adaptation option for the villagers exposed to higher erosion risks. Apart from retaining wall, local practice of village protection is cheapest and can be improved and disseminated to wider communities.

Local people practice low cost measures to protect their houses from wave erosion. Villages along the border of Indian Meghalayan Hills collect big sized boulders from the hilly streams and rivers make stake on the slopes of courtyard and houses. Some people plant *koroch (Pongamia pinnata)* trees (tree variety that survives in inundation conditions) just below the boulder stakes in the form of green belts. These bolder stakes and koroch trees collectively provide protection to houses against wave induced erosion. People who live at distant place from the border and access to boulders is not easy, they practice chailla–bamboo–mud bunds to protect their houses. Chailla is a kind of tall grass that naturally grows in haor areas during dry season and bundle of such grass mixed with mud and fixed with bamboo poles gives a spongy effect to wave action and thereby reduces the strength of wave and thereby wave induced erosion is protected. But this technology last for 1 year and people are to fix these bunds every year. On the other hand the boulder made protection measures last for few years with initial higher costs.

16.6.2 Houses Protection in Flooding Areas Including Coastal Zone

Houses on raised plinths: Flooding and inundation has been a major problem in the central floodplains including the charlands of the rivers of Ganges, Brahmaputra–Jamuna and Meghna since long. Every year during monsoon months people live in these areas suffers from inundation of their homesteads and houses due to higher flooding depths over variable time frames depending on land elevations. This problem of inundation of homesteads including houses has recently been experienced in some low lying coastal areas. Recently, apart from cyclones and storm surges, in some coastal areas villagers experience inundation of their homesteads and houses even during high tides which they see as a new dimension of threat not existed before. This problem may have been linked to sea level rise as a result of global warming. Besides, people in coastal Bangladesh faced two devastating cyclones namely Sidr and Aila in 2007 and 2009 respectively when thousands of coastal houses were inundated by saline water for variable times. After the cyclone Aila and Sidr many households in the low lying coastal area were assisted by the government and NGOs to make their houses on raised plinths to get protected from coastal flooding either due to abnormally high tides or cyclones and storm surges. CARE Bangladesh through its Flood Proofing Project demonstrated making of houses on raised plinths in riverine char lands of Brahmaputra River systems to protect from flood hazards in late 1990s which now being replicated by other actors in the wider char lands (CNRS 1998).

Settlements/village on raised lands: After the devastating cyclones *sidr* (*2007*) and *Aila* (*2009*), government of Bangladesh through CDMP-II demonstrated an innovative idea of raising the whole settlement or village rather raising the individual house plinths and named it as "climate resilient habitat" where all the families have houses built on raised village and hence the whole village is free from coastal inundation. The design has provisions for common places like separate ponds for bathing and drinking, community center, small market, payer places, etc. so that other necessary livelihood facilities are also safe from coastal flooding.

Mud wall housing: Dwelling houses with mud wall is not a new technology rather an old technique in drought prone areas in North Bengal and other areas in the north and south to protect themselves from heat waves. In the current event of increasing temperature due to global warming, more people are now making mud wall dwelling houses where warming affect is acute. Earthen wall is cheaper and can be made out of locally available materials (clay) and the technology is easier and known to the people. Earthen wall made houses are liked by the poor for its excellent thermal properties that gives soothing environment inside compared high temperature outside. This technology is a suitable adaptation option for people in areas with severe weather conditions.

Cyclone resistant housing: Coastal area of Bangladesh is prone to cyclones, storm surges and high winds that affect people the most live in the exposed coasts. The tropical cyclones often come with very strong winds with as high as over 200 km/h which damages houses that are mainly made up of tin roofs with kuccha (bamboo splits) wall and earthen plinths. IUCN Bangladesh demonstrated building of cyclone resistant housing during 2006–2008. The recommended house structure strengthening the weak areas of traditional house structures and then incorporated strengthening measures in to it keeping the core design structure roughly unchanged (Mallick et al. 2008). These high wind or cyclone resistant house structure adopted some key principles:

- House should offer minimum wind obstruction, keep the roof pitch between 25° and 35° to minimize suction caused by negative pressure,
- Avoid large overhangs, separate veranda coverings and frames from the main roof,
- Make sure of strong fixings and joints between all elements of the house and fixing must be good enough and frequent enough to stop the structure form breaking,
- Balance the size of openings in opposite walls and make sure all opening can be closed,
- Planting of trees and bushes to reduce wind act as wind beaker.

Reinforcement of coastal fishing of boats: Boat capsizes is a common event in the coastal fishing. Key reasons for boat capsize as described by the fishers that hitting of boats with submersed chars (san bars) in the coast during strong winds or cyclones for breaking of boats and finally capsized. IUCN jointly BUET researchers conducted a boat capsize assessment and designed along with the fishers and local boat makers. The team reinforced the boat with installation of iron sheets with frequent fixing with the wooden bars across the boat that holds the wooden bars together so that woods remain together while the boat get hit with chars during high winds (Rahim 2008). This technology of boat reinforcement can sustain hitting and thus can sustain during high winds. With little additional costs the fishers can protect boats from being lost and thus can save their lives and assets from high winds and cyclones.

16.7 Potentials for Furthering the Adaptation Technologies

Bangladesh experiences different types of climate induced disasters very frequently such as flood, drought, cyclone and storm surge which triggers a whole set of mechanism that affects the economic and social lives of people. Adaptation technology is a location and hazard specific concern and people living in vulnerable zone are comparatively poor or marginal and subsistence farmers or fisher communities. They are resilient and adapt with the situation with their traditional knowledge and coping technology. But over time climate change scenario is deteriorating and peoples' indigenous knowledge and local wisdom as well as coping strategies seem likely to address the threat without appropriate technology support and necessary skills. In response to this upcoming scenario in an age of climate change with lots of uncertainties, it is need of the time to emphasize on scaling up existing current practices, development, promotion and diffusion and adoption programme at short term, medium and long term targets. Technology is created in response to market pressures-not the needs of poor people, who have little purchasing power. Research on and development of technologies for poor people's needs have long been ignored and underfunded. Since it is estimated that 17 % of the coastal area would be submerged due to sea level rise which in turn would transform a large area of fresh water ecosystems into saline, there is a massive potential need for technologies to adapt to coastal and marine based livelihood means which still largely remains as an ignored sector in Bangladesh. There is no dedicated source of funding for such preparation and commitments to technology transfer are central to many international agreements but many of those provisions are either ignored or inadequately implemented.[1]

16.8 Conclusion

Slow on-set persistent climate induced disasters require advance planning for long-term solution with adaptation technologies which involve investment for research and development against different climate change scenario. Building local technological capacity is central to forging long term solutions because technologies for development cannot and will not be supplied through the global marketplace alone. Promotion, scale-up, development and diffusion of adaptation technologies need attention in the area of climate resilient agriculture, energy, infrastructure, transportation, and construction, health care and so on. Being a least developed country with high population pressure, major concern is to maintain food security and ecosystem based livelihood opportunities in the face of changing climate. A number of technologies are in practice in the agriculture sector in different geographical locations have specific climate related stressors that necessitate specific adaptation technologies and options. Some adaptation initiatives to address increased disaster risks due to climate change and some piloting are done in disaster prone areas of the country have good lessons need to be documented for wider dissemination. Although various climate change adaptation project/activities are ongoing, stock taking of adaptation technologies in practice in geographical locations has not done yet for analysis of their effectiveness and further improvements.

References

BRRI (2012) Achievement of Bangladesh Rice Research Institute – modern varieties. Available at http://www.knowldgebank-brri.org/. Accessed 16 Dec 2012

[1]UNDP (2001) Human Development Report 2001: Making New Technologies Work for Human Development, New York.

Chowdhury SR, Hossain MS, Shamsuddoha M, Khan SMMH (2012) Coastal fishers' livelihood in peril: sea surface temperature and tropical cyclones in Bangladesh. CPRD, Dhaka, 54 pp
Clements R, Haggar J, Quezada A, Torres J (2011) In: Zhu X (ed) Technologies for climate change adaptation – agriculture sector. UNEP Risø Centre, Roskilde
CNRS (1998) Socioeconomic and flood vulnerability survey in selected char areas of the Brahmaputra River systems, Flood Proofing Project (FPP), CARE Bangladesh, Baseline Survey Report, Dhaka
CNRS (2011a) Climate resilient farming systems in the Haor basin of Bangladesh, Project Report, CNRS, Dhaka
CNRS (2011b) Adaptive Crop Farming Demonstration under the Wetland Biodiversity Rehabilitation Project (WBRP), Technical Report, CNRS, Dhaka
CNRS (2011c) Focus Group Discussions, Fish Traders, Kolbari Fish Landing Center, Shyamnagar sub-district, Satkhira
CNRS (2012a) Piloting some Climate Resilient Development Initiatives at Char Kajol, Golachipa, Patuakhali – An Innovative Concept of CBA to CC, Second Quarterly Report to UNDP, Dhaka
CNRS (2012b) Focus Group Discussions, shrimp farmers, Chakbara Village Shayamnagar sub-district, Satkhira
CNRS (2012c) Lessons learning report, CNRS. Shiree, 50 pages, Dhaka, Bangladesh.
Cruz RV, Harasawa H, Lal M, Wu S, Anokhin Y, Punsalmaa B, Honda Y, Jafari M, Li C, Huu Ninh N (2007) Asia. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 469–506
CSISA (2012) Farmers manual on improved rice farming technologies. Cereal Systems Initiative for South Asia in Bangladesh, IRRI (in Bangla)
De Silva SS, Soto D (2009) Climate change and aquaculture: potential impacts, adaptation and mitigation. In Cochrane K, De Young C, Soto D, Bahri T (eds) Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO. pp 151–212
Ferdoushi AS, Bolkland WM (2000) Design Improvement for pond sand filter, World Bank, Dhaka, Bangladesh
Ferdoushi Z, Xiang-Guo Z (2010) Economic Analysis of Traditional Mud Crab (Scylla sp.) Fattening in Bangladesh. Marine. res. aqua. 1(1)
IPCC (2007) Summary for policymakers. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds) Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge
Islam N, Rabbani G, Rahman AA (2010) Climate change and sea level rise: issues and challenges for coastal communities in the Indian Ocean. In: Michel D, Pandya A (eds) Coastal zones and climate change. Stimson: Regional Voices, The Henry L. Stimson Center, Washington, DC, pp 17–30
Kulkarni S (2011) Innovative technologies for water saving in irrigated agriculture. International Journal of Water Resources and Arid Environments 1(3):226–231, ISSN 2079–7079
Mallick FH, Ahmed KI, Kabir KH, Kabir MH (2008) Improved design and construction of rural housing in noakhali. IUCN Bangladesh Country Office, Dhaka, Bangladesh, p 44
Mirza MMQ (1997) Hydrological changes in the Ganges system in Bangladesh in the post-Farakka period, Hydrological Sciences Journal, 42:5, 613–631
MoEF (2005) National Adaptation Programme of Action (NAPA), Ministry of Environment and Forests, Government of Bangladesh, Dhaka
MoF (2012) Bangladesh Economic Review 2012. Economic Division, Ministry of Finance, Government of Bangladesh, Dhaka
MPO (1986) National Water Plan, Prepared for the Ministry of Irrigation, Water Development and Flood Control, Government of Bangladesh and UNDP and the World Bank by Harza Engineering Company International and Sir MacDonald and Partners

PDO-ICZMP (2004) Where land meets the sea: a profile of the coastal zone of Bangladesh; and Bangladesh Bureau of Statistics 2001 Census
Rahim A (2008) Study on fishing boats of coastal belts of Bangladesh: an investigation of accidents during cyclonic weather. IUCN Bangladesh Country Office, Dhaka, Bangladesh. Vii p 46
Rahman MM (2012) Strategies to strengthen current adaptation measures of the project, Community-based Adaptation to Climate Change through Coastal Afforestation project, UNDP, Dhaka
Rahman M, Siddque M (2012) Environmental Management Plan (EMP) and Environmental Management Framework (EMF). FtF Aquaculture Program, USAID, WorldFish, Bangladesh and South Asia Office, Dhaka
Swapan MSH, Gavin M (2011) A desert in the delta: participatory assessment of changing livelihoods induced by commercial shrimp farming in Southwest Bangladesh, Ocean & Coastal Management 54, 45e54
Tuong TP (2007) Alternate wetting and drying irrigation: a technology for water saving in rice production. Crop and Environmental Science Division, International Rice Research Division, Los Banos, Philippines (Paper presented in the crop cutting ceremony, BADC Farm, Modhupur, Tangail)
UNDP (2012) Mid-term evaluation of community based adaptation to climate change through coastal afforestation in Bangladesh. UNDP, Dhaka
Warner K, van der Geest K, Kreft S, Huq S, Harmeling S, Kusters K, de Sherbinin A (2012) Evidence from the frontlines of climate change: loss and damage to communities despite coping and adaptation. Loss and damage in vulnerable countries initiative. Policy Report. Report No. 9. United Nations University Institute for Environment and Human Security (UNU-EHS), Bonn
World Bank (2000) Bangladesh: climate change and sustainable development. Report No. 21104-BD. Rural Development Unit, South Asia Region, The World Bank (WB), Dhaka
World Bank (2002) World development

Chapter 17
Habitat and Infrastructures: A Localized Approach to Resilience

Fuad Mallick

Abstract Habitat and infrastructure is central to all the aspects associated with human life and living. While climate change is an all important issue, adaptation of human habitat and the physical infrastructure remains a key challenge to address. The concept of resilient built environment stems from the idea of lessening disaster impacts as well as quickening the recovery process. As hydro-meteorological disasters are likely to increase in terms of frequency and intensity as a consequence of global climate change, vulnerable community needs a more resilient built environment. But all the technically sound options are not viable for communities with resource constraints. This chapter describes how an approach incorporating local knowledge and skills with realizable technical knowhow can help building a better resilient community. Flood and cyclone are considered in this instance. For flood, the concepts elaborated here are yet to be realized. For cyclone, two realized case studies are presented. The core objective of this chapter is to address the importance and usefulness of looking at the "process" of building infrastructure rather than looking at the "product" in isolation. The "process" refers to involving community in the generation of design ideas and also respecting the local knowledge and skills in the construction procedure thus imparting the real sense of ownership to the community. While adaptation to climate change is the concern, such sense of belongingness by the community can help make it better.

Keywords Climate change adaptation • Coastal • Community infrastructures • Habitat • Resilience

F. Mallick (✉)
Postgraduate Programs in Disaster Management (PPDM),
BRAC University, Dhaka, Bangladesh
e-mail: fuad@bracu.ac.bd

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*,
Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_17, © Springer Japan 2013

17.1 Introduction

It goes without saying that if we are able to create habitats and infrastructure that adapt to climate change appropriately then we need not worry about the issue as much as we do. But the multifarious aspects of climate change and variability make this a difficult task. Furthermore we are not entirely sure about the extent of the likelihood of all the predictions of climate change coming true; some may have been overstated and some under. Nevertheless that climate change is a reality is evident (IPCC 2007). The need to adapt to it is becoming more and more of an issue as we continue to experience its effects. On the one hand there are many aspects that need adaptation e.g. livelihoods, agriculture, food security, migration and so on, the issue of adaptation of habitat and infrastructure need a more practical and down to earth, perhaps to a large extent engineering and architectural, solutions. How much these need to be top down and how much bottom up also needs to be understood. Adaptation of habitat and infrastructure is not a standalone issue; they are related to other aspects of climate change adaptation. The ability to understand these interconnections is the key element that will help us address the problem.

17.2 Concept

One of the effects of climate change is the alteration in frequency and intensity of hydro-meteorological events (IPCC 2012). In this case of relevance to Bangladesh are cyclones and floods.

There have been several cyclones in recent years. Because of innovative approaches in mitigating cyclone disasters such as cyclone shelters, early warning systems, and the Cyclone Preparedness Program (CPP), casualties have been greatly reduced. As opposed to about 300,000 deaths in the cyclone of November 1970 and 138,882 or so deaths in 1991 (SMRC 1998), there were only 3,363 deaths because of cyclone Sidr and an even lesser number, 190 for cyclone Aila (Disaster Management Bureau website). However, Aila has long term effects on housing, infrastructure and livelihoods, the consequences of which are far reaching and can even be seen now.

Early warning systems for flood disasters have also lessened the instances of deaths not only due to the floods themselves but also deaths due to post flood epidemics. The makeshift hospitals provide medical services to the victims at very basic level, and these have reduced mortality and morbidity.

The challenge lies in developing creative adaptive responses to the effects of climate change induced disasters such as floods and cyclones. If a situation can be reached where housing and infrastructure receive less or no damage and life can quickly return to its original pace after a disaster event it could quicken the recovery process (Mallick and Rahman 2008). The key issue here is creating a resilient built environment, one that is not completely destroyed or washed away. There are of course technical solutions to these but to make an infrastructure completely resistant to floods or cyclones is way too expensive. The second challenge within is to seek affordable and buildable solutions.

17.3 Realizing the Concept

The first step towards realizing the concept of resilience is to look within. To identify skills that exists within the community and finds ways improving them and making them possible from the technical point of view. Two kinds of forces come into effect here. The first being effective local skills and knowledge and second to complement them with realizable technical knowhow. The first obviously comes from the community and the second from technically qualified people such as architects and engineers and supported by masons, carpenters etc.

These two forces have to come together to firstly identify the knowledge gap that exists in each and then fill them up. Working side by side with the community will help arrive at solutions that can be implemented.

The chapter looks at three examples where this has been implemented; for the flood situation, looking at indigenous ways of coping with floods and the working of institution-built flood shelters. For cyclones there are two examples of strengthening houses and infrastructure in two locations in Bangladesh.

17.3.1 Floods

Rural houses in Bangladesh's flood prone areas have been coping with floods for centuries. In fact floods are a part of the lives of these communities and they have their own coping mechanisms (Fig. 17.1). They build on raised ground and plinths. What becomes a problem is when floods last for a long time and connection to community is lost, potable water become scarce and unsanitary conditions prevail for extended periods.

A comparative analysis of different types of flood shelters in Bangladesh (Rahman et al. 2010) suggests that people have their own means of coping with floods, they are often not adequate. Some innovative inputs can be applied to these known solutions to make them work better. For example stabilizing the plinth with a 5 % cement mix renders them stronger. Also using geo-textiles and certain types of plants along the slopes of the raised homestead makes the ground more stable.

One solution goes on to suggest floating houses where each house rises with the floods and remains anchored in place, while another proposes an easily dismantleable flood shelter, so that it can be moved to higher ground if necessary (Fig. 17.2).

As such embankments are built to keep away the flood waters and during floods the affected people take shelter on them. One approach could be to plan these embankments in way that they widen at certain points to house a shelter or a market (Fig. 17.3) and they are connected to the homesteads.

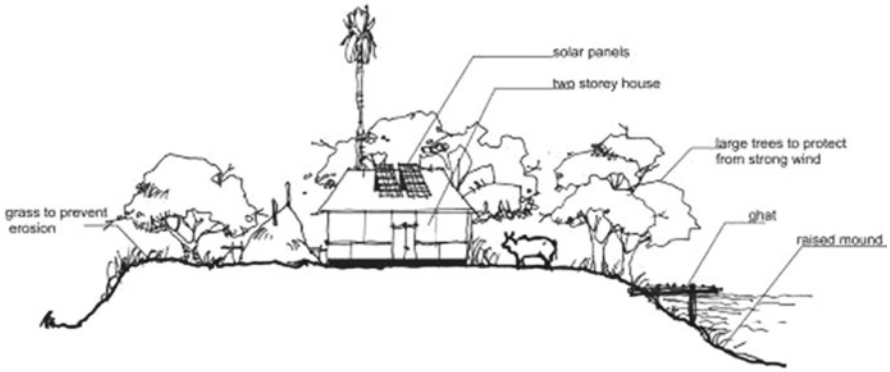


Fig. 17.1 Adapting homesteads for floods. *Source*: Rahman et al. (2010)

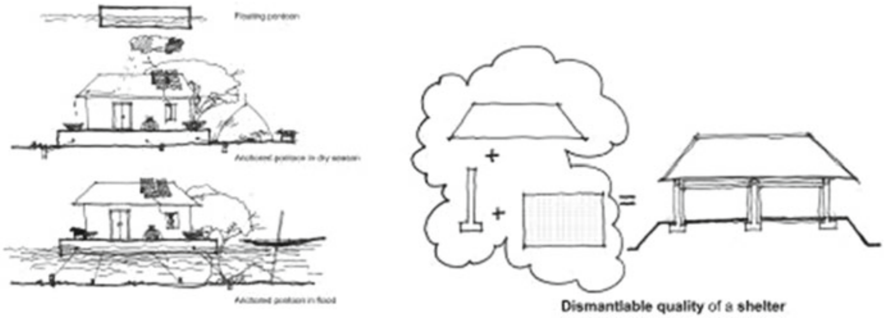


Fig. 17.2 Dismantleable shelter and floating houses. *Source*: Rahman et al. (2010)

Not all these solutions have been tried, as they are still at idea level, but very much implementable given some more technical input e.g. the design of the pontoon and the joinery details of the houses.

17.3.2 Cyclones and High Winds

Cyclones in their aftermath leave a lot damage, much more than floods and in a shorter span of time. Given the nature of construction in the rural areas of Bangladesh's coastline, the houses are highly susceptible to destruction, often total. The number of houses that were totally damaged by cyclones Sidr and Aila were 564,967 and 243,191 respectively (Disaster Management Bureau website). When a household's shelter is totally destroyed, and if they are poor there is little chance of rebuilding the houses immediately. They would then live in makeshift shelters on high embankments, perhaps for years on end.

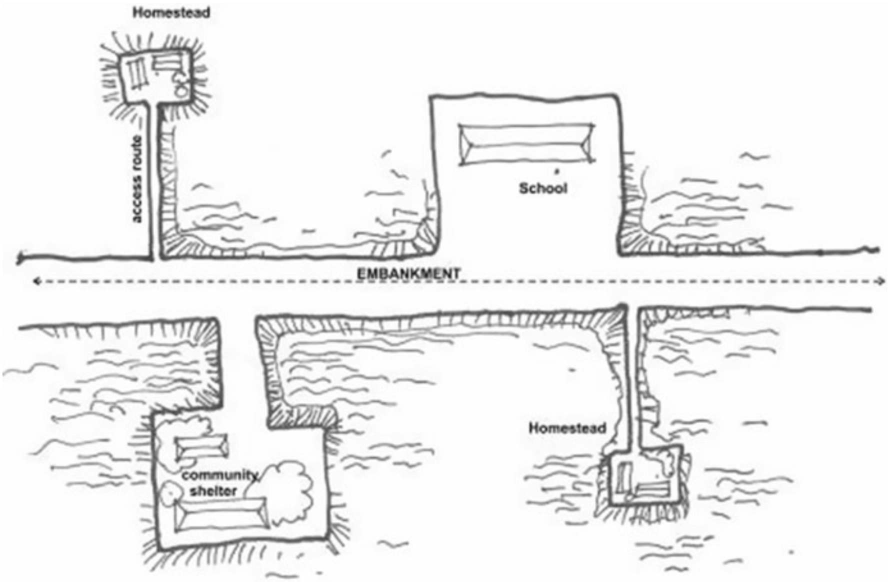


Fig. 17.3 Embankment design for adaptation to floods. *Source*: Rahman et al. (2010)

The concept realization approach here is again to combine local knowledge with technical knowhow. While it may not be possible to design and build indestructible houses for cost reasons, it may be possible to build ones that suffer less damage. The idea is to create a structure which if destroyed is not totally so but to the extent that it can be rebuilt quickly.

17.3.3 Process and Product

Building such houses and infrastructure, while it can be a top down process, it isn't always effective. There is no sense of ownership and if there is no participation of the occupants in the process there is no motivation to improve upon it. The idea that was stressed here is one where the process of design and construction is more important than the product. The understanding being that if the process is correct the product will be too.

The process involves all the stakeholders i.e. the homeowners, the mason and carpenters and the architects and engineers. It involves the combined pooling of resources and ideas to design and build houses that are more resistant to high winds than a normal structure is. The process starts with the sharing of ideas and identifying skills and gradually evolves into a buildable design solution. Dialogues are held amongst all to better understand each other and to know where ones role lies in the process.

17.4 Two Houses and Two Schools in Noakhali

A small project funded by IUCN called for the strengthening of two houses and retrofitting of two schools, against cyclonic winds in the Noakhali region of Bangladesh. The budget was quite low and the idea was to base the strengthening on existing construction methods.

The community representatives along with some masons and carpenters met with architects and students at the Department of Architecture, BRAC University (Fig. 17.4). They developed a design which incorporated some simple means of strengthening the houses. This included deeper foundations, cross bracing of the house frame and stronger joints in the roof frame with narrower purlin spacing in lower side of the sides of the frame.

Next steps consisted of actual construction on site with some more safety option incorporated during the construction process.

For the schools the entire one storey structure was stripped to reduce it to it bare frame, which was then strengthened with cross bracings and stronger ties.

The results achieved evolved as the end result of a process, where the house owner, and the community, participated with engineers, architects, masons and carpenters is developing a design that suited the needs and the means.

Fig. 17.4 Stakeholder consultation at the design phase (*top two*) and a house (*bottom left*) and the school (*bottom right*) of the Nokhali project. *Source*: Khandoker Hasibul Kabir, Department of Architecture, BRAC University

17.5 A Climate Resilient Habitat in Satkhira

This is also called a “Disaster Resilient Habitat” but the word “disaster” could be replaced quite easily with “climate” as it serves both purposes. The area, which was not very cyclone prone, have recently been hit by two cyclones, Sidr and Aila, unusual events that could be attributed to climate change.

As a result of cyclone Aila this community of 43 households not only lost their homes and livelihoods but also became subject to tidal flooding because the embankments that protected them were damaged. This damage was not only due to the cyclone but also a result of man induced weakening of them. Holes were made in them to bring in saline water for shrimp farming, thus weakening them.

The objective of the project, funded by UNDP and realized by BRAC University and BRAC, was to rehouse the affected households in homesteads that were resistant to cyclonic winds and to an extent storm surges. It was not possible to provide the entire space requirements of the households, hence part of the homestead would be raised and the space underneath could be used by the people build what they needed.

Again, the process took precedence over the product. A number of consultation sessions were held with the community both on site and in the studios of the Department of Architecture (Fig. 17.5). Experience from the project in Noakhali was also added to the information flow that took place. It was discovered that the

Fig. 17.5 Stakeholder consultation at the different stages of the design procedure for the climate resilient habitat project in Satkhira. *Source*: Khandoker Hasibul Kabir, Department of Architecture, BRAC University

Fig. 17.6 Individual house construction in progress for the climate resilient habitat project in Satkhira. *Source*: Khandoker Hasibul Kabir, Department of Architecture, BRAC University

Fig. 17.7 Independent modifications and extensions at the post-basic construction phase. The *bottom-right* is the photograph of the school-cum common shelter. *Source*: Khandoker Hasibul Kabir, Department of Architecture, BRAC University

community had good carpentry skills because they were boat makers. The engineers designed the frame on which the houses would stand given the tough site conditions and bad soil (Figs. 17.6 and 17.7).

The site had been made saline by the breaches in the embankments hence casting a concrete frame proved difficult. The responsibility of providing fresh water for the concrete was given to each homeowner to ensure quality. The design evolved as the process went on and revisions and corrections were made to them as the process developed. A group of architects stayed on site to supervise the construction.

The basic design called for a timber frame house sitting atop a concrete frame of 9 ft × 12 ft. The timber frame was firmly attached to the concrete frame with on-site designed joinery. The homeowners' boat-making skills were used to build the strong wood frame made from timber that had been sourced from trees that had been replanted. The roof was made with tiles, the area being famous for producing good quality ones. Since the tiles were susceptible to being blown away by winds each one was screwed on to the roof frame.

The space below the houses could be used by the homeowners to construct makeshift or even permanent additions, thus extending their space. The house on the concrete frame need not be used all the time and in emergencies they could provide shelter to the household or perhaps even some neighbors.

A school was added to the scheme, replacing the one that was lost in the cyclone. A part of the land around the school was raised to adjoin it and would serve as a place of safety for cattle during a cyclone. Raising the houses on concrete stilts would also make them useable should sea level rise happen to the extent that the surroundings are inundated. In that case the community would have to rely on boats for transportation and grow saline resistant variety of crops.

17.6 Conclusions

Adaptation to climate change requires the participation of many actors, government, non-government and particularly the people who the adaptation is for. Of the instances of floods and cyclones mentioned in this chapter, the suggested action for floods had been consolidated after consultation with the community. In the case of stronger houses and the climate resilient habitat the people actually participated in the process.

Sense of ownership is important in the adaptation process for it to succeed. Although the overall responsibility may lie with the government or other agencies, eventually it is the people who will be facing the challenges. Thus participation in the process gives them a better understanding of the issue and perhaps be more aware of climate change as a whole.

References

Disaster Management Bureau (2012) [website]: Retrieved July 30, 2012, http://www.dmb.gov.bd/pastdisaster.html

IPCC (2007) Summary for policymakers. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds) Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

IPCC (2012) Managing the risks of extreme events and disasters to advance climate change adaptation. In: Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KL, Mastrandrea MD, Mach

KJ, Plattner G-K, Allen SK, Tignor M, Midgley PM (eds) A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, 582 pp

Mallick FH, Rahman MA (2008) Cyclone shelters and alternatives for sustained development in Bangladesh. J South Asia Disaster Stud 1(1):59–67 (SAARC Disaster Management Centre, New Delhi, India)

Rahman MR, Mallick FH, Mondal MS, Rahman MA, Rahman T (2010) A comparative analysis of different types of flood shelter in Bangladesh. DIPECHO Partners in Bangladesh

SMRC (1998) The impact of tropical cyclones on the coastal regions of SAARC countries and their influence in the region. SAARC Meteorological Research Centre (SMRC), Dhaka

Chapter 18
Community Based Adaptation: Theory and Practice

A.K.M. Mamunur Rashid and Mizan R. Khan

Abstract Community-Based Adaptation (CBA) has emerged as a notion in climate change discourse given to its extensive span as 'practice area'. This is now widely practiced in Bangladesh particularly since 2002. In other parts of the world also, CBA is also an action area particularly after climate change impacts have begun to unfold in terms of increased climate disasters in recent years. Till now CBA has been conceived by the development practitioners as an effective approach to reduce vulnerability of the poor and marginalized people from climate change impacts. This was done under the framing of participatory development that was conceptualized in the 1970s and 1980s. Historical accounts reveal that the seed of thoughts on CBA is rooted in Taoism, which was developed in 600 BC in China. Now because of climate change, it is viewed that CBA as a practice area has come to stay. Therefore, it's time to synthesize the practice experiences around the world into some form of coherent theories and concepts, so that it can play an effective role in strengthening adaptive capacity of the poor communities around the world. This chapter attempts to lay down a conceptual framework for the CBA, so that it can proceed further into its application with theoretical and methodological rigor. Our discussion on conceptual framing is substantiated by two case studies of CBA in southwest of Bangladesh, which we argue had sound conceptual and methodological rigor in their designing and implementation. Our conclusion is that CBA programme has to be people centered, process oriented, community led, knowledge

A.K.M.M. Rashid (✉)
Poverty Environment and Climate Mainstreaming Project,
UNDP Bangladesh, Dhaka, Bangladesh

Department of Anthropology in Jahangirnagar University, Dhaka
e-mail: nemoibsru@gmail.com

M.R. Khan
Visiting Scholar at Brown and Professor of Environmental Management
at North South University, Bangladesh

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*,
Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_18, © Springer Japan 2013

oriented, empowerment focused and accountability driven. And all these aspects constitute major areas of further academic research and analysis.

Keywords Climate change • Climate change adaptation • Community based adaptation • Community based development • Community led development • Practices • Theory

18.1 Community Based Adaptation: Theoretical Underpinnings

"Community Based Adaptation" as a term has emerged from community based programmes in climate change sub-sector, disability sectors and poverty reduction sectors as a "terms of convenience". This is largely based on a community based approach to development, and climate change adaptation here is considered as a development issue. There is no agreed definition of "community based approach". However, there are many popular philanthropists (Paulo Freire 1921–1997; Gandhi 1962; Richard Ho Lung as founder of Missionaries of the Poor, and others) and academic scholars and researchers (Mikloucho-Maclay 1950; Malinowski 1922; Chambers 1983, 1992, and others) who has provided basis or popularized the idea of community based approach in development by encouraging the "community" as active agent of knowledge not as only passive recipient of knowledge. Though we find the idea of community led approach in Lao Tzu's (BC 600–525) poem, who founded the Taoism in China. There is also dual qualifier used in community development: community *based* and community *driven*. This difference refers a serious lack in the theoretical development in the community development. There are approaches in community development, but no such grand theories. The landscape of many of these theories is deeply rooted in the "concept of participation" developed in nineteenth century (Mikloucho-Maclay, 1871–1883 field work in Papua New Guinea) and early twentieth century (Malinowski 1922 field work in Trobriand Islands), for the development of empiricism and in 1990s of twentieth century (Robert Chambers 1992 and others) in rural development.

We need to discuss two philanthropic traditions in India and South America led by Gandhi and Paulo Freire to begin the layout of professional community development programme. India has a long history of community-based forms of development. Clearly significant were the cooperatives tested by the poet Rabindranath Tagore and Gandhian notions of village self-reliance and small scale development (Gandhi 1962), which Gandhi perceive as a remedy to the penetrating effects of modernization and colonial rules. Another influential perspective was offered by (Freire 1970) in his book *Pedagogy of the Oppressed*. Freire argued that the oppressed needed to unite to find a way to improve their own destinies. These two philanthropic idea of community based or community led development drive the first-wave of participatory development in the 1950s, which by 1960s had spread to more than 60 countries in Africa, Asia, and Latin America, largely through the USAID (White 1999). These were never seriously evaluated, and the knowledge of such initiatives was almost lost as the funding from USAID dried up. Such artificial conditionality for receiving aid has an impact on it, and aids were influenced by strong economic models with robust idea of 'big development'. At the beginning of mid-1980s critics of "big development" appeared in scene and start complaining that a large number of big, government initiated development programmes were performing poorly but rapidly degrading common pool resources and causing negative environmental and poverty impacts. Then again the participatory development movement was revitalized and this time this was led by Schumacher (1973) and Chambers (1983) arguing small-scale development in ways that would allow the poor to be informed participants in development, with external agents acting mainly as facilitators and sources of funds. This idea of seriously supported by academic social scientists, such as Escobar (1995) and Scott (1998) arguing top down perspectives were both disempowering and ineffective. The issue of ownership and empowerment therefore came strongly as key issue of development during 1990s and even now pre-dominant as key ideology in development.

Historical trajectory reveals that the seed of thoughts on CBA is rooted in Taoism, which was developed in 600 BC in China. Taoism offered the basic fundamentals of 'the way'. The root of Tao is defined as the way of the universe, nature and balance; it is a reality that cannot be grasped in language or thought. The underlying basis for Taoism lies between the philosophical and religious poles, as an epistemic idea. Both poles of Taoism start from a common critique of "ordinary" knowing of tao (way guide). From this mildly skeptical or relativist base, philosophical Taoism tends toward pluralism, perspectivalism, skepticism, political equality and freedom. In his poem, the founder of Taoism Lao Tzu (BC 600-525) has outlined the philosophy of participatory development and narrated the idea of community based development 2,600 years ago. He wrote,

> Go to the people.
> Live with them.
> Learn from them.
> Love them.
> Start with what they know.
> Build with what they have.
> But with the best leaders,
> when the work is done,
> the task accomplished,
> the people will say
> 'We have done this ourselves'.
> – Lao Tzu (BC 600–525)

While contemporary community based development programs do not conform rigidly to a set of predefined criteria, most community based programs are based on a number of key assumptions. The seven principles are found represent important assumptions of the community based approach that emerged over the last 150 years. The seven distinct principles though they are separated, there is considerable overlap between the individual principles. Most of the principles are a matter of degree rather than all-or-none phenomena. The seven principles are: (1) community focus, (2) community member's participation, (3) inter-sectoral collaboration, (4) substantial resource requirements, (5) long term programme view, (6) multifaceted interventions, and (7) population outcome (Nilson 2006).

The theory of community based development influenced the genesis of community based adaptation. The broad hypothesis is while the problem is global the action has to be local. The issue of climate change adaptation came into force with an assumption that change is certain (IPCC 4th Assessment Report) and dynamic and we have to adapt to change. This has bring the people into the centre of the discussion again, and community based adaptation has grown up under the generic community based development philosophy with some specific uniqueness. One of the unique differences is that climate change is future risk and this is not quite familiar at community level and the indigenous knowledge has a limit to use to combat such uncertain and long term prediction. This CBA programme cannot fully based on past experience of the ancestor and there is need of external knowledge in the programme, which is different from classic community driven programme. Another important aspect is new technologies needs to be developed where scientific community has to work with community and a technology transfer is inevitable. However, this uniqueness does not mean that we will not get benefit from the ancestor knowledge, nor this mean that we cannot rely on people's own knowledge and creativity to discover new solutions to address additional stress to their well being due to the climate change. One of the greater challenges is in many cases, climate change is not evident at this moment on ground, we have to work on a broad assumption and community has to accept that risks in future. Until community accept and believe the future risk, whole process of building adaptive capacity to the community will not be sustainable. This modality is new in community based development approach, where participatory visioning has to be smartly used for participatory risk (susceptibility) projection and draw the solutions as a whole not only as per single element.

There is no grand theory around community based adaptation. The practitioners are consolidating their past 10 years experience in community based adaptation work along with academicians and drawing key principles for community based adaptation. Many people (Bettina and Annecke 2010; CARE 2010; Haq 2008) have argued that CBA has no such clear definition rather this is an emerging approach to address climate change adaptation needs. As an approach, CBA put people in the centre of their own development; facilitate the community towards a learning process to increase their resilience and anticipatory capacity. The anticipatory capacity or resilience do not mean here response to climate events and shocks, but focus on their ability to project a future risk scenario based on broad predictions from scientific community blending with their own experiences and to have proactive measures and wisdom to invest to protect, absorb or accommodate future risk scenario. This also refers a transfer of future risk knowledge through enculturation process. The proactive measures refer a holistic and set of organic process of coordination that includes personal, societal, and ecosystem capacity building in a scale, which can enable them to create a positive vision to achieve by small add on development from today. This wisdom is a key feature in the CBA approach.

In that context, CBA has to a greater extent depended on external resources for knowledge, technology and finance, which is categorically different from other community based approach. This difference is for many causes, one of them is about justice. The people usually likely to suffer in climate change and naturally compelled to adapt to such changes are not caused by themselves. The innocent victim of climate change are usually less contributor and the historical responsibilities therefore lies on others to assist them in adapting to climate change. Therefore, finance is a different character here in comparison to other types of community based programmes. The communities which are usually vulnerable are most likely to expose to climate change impacts, and therefore they have limited capacity to invest in inventing new technology and techniques to adapt to climate change. This condition demands a need for knowledge and technology to adapt to climate change outside the community in addition to their own knowledge and technology. This difference demands to reframe the term "Community Based Adaptation" as "Community Led Adaptation", where leadership will remain to community, their cultural way and governance needs to the basis to utilize the external resources, knowledge and technology. They should have the final say about accepting or rejecting the knowledge, technology and resources. This uniqueness along with key principles of a community based development features will constitute the characteristics of a community led adaptation programme.

18.2 Practices of CBA in Bangladesh: Two Case Studies

18.2.1 Case-1: Advancing Capacity for Climate Change Adaptation (ACCCA) Project of UNITAR in Bangladesh

Participatory Climate Risk Assessment and Development of Local Adaptation Action Plan is a pilot adaptation project jointly implemented by North South University and Area Development Organization in Assasuni Upazila (sub-district) of Satkhira District, Porsha Upazila of Naogaon District and Keshobpur Upazila of Jessore District in Bangladesh. The project was 18 months long with a cost of USD 70,000 financed by ACCCA during 2007–2008. The project had four broad objectives: (a) increase capacity and motivation of communities and Local Government entities' to assess community risks to climate change and variability following a participatory process, (b) build confidence of Local Government entities and enhance skills of community people in developing stakeholder-inclusive climate risk reduction (adaptation) plans of action at community and local government levels, (c) increase awareness of multi-level stakeholders on livelihood risks to climate change and variability and adaptation options to facilitate government and development agencies' buy-in and mainstreaming climate change issues, and (d) increase confidence of the multi-level stakeholders on replicability of the identified local level livelihood adaptation strategies.

The project has oriented the Union Parishad on climate change issues, conducted participatory community level climate change risk assessment, assisted the local government in developing a climate change adaptation plan at community level, organized awareness campaign on the implementation of the climate change adaptation plan, advocacy for mainstreaming climate change plan into local development, undertaken a few household level climate change sensitive livelihood adaptation options, disseminated the successful livelihood adaptation options through school sessions to students and awareness raising to the farmer and women. The project was implemented in three contexts: sea level rise and salinity context, flood and waterlogging context, and drought context.

18.2.1.1 Pilot Climate Change Sensitive Livelihood Adaptation Options

Community based pilot adaptation actions were selected from the climate change risk assessment and local adaptation action plans for implementation at household level among the 120 highly vulnerable households (40 Poor and Marginal Farmers, 20 Agri-labourers, 20 Landless Women, 20 Indigenous People and 20 Small Traders). The adaptation processes in flood and waterlogged area were hydroponics, duck rearing, ring-based vegetable cultivation and charu (fish trapper) making and in saline prone area, adaptation processes were mat weaving by reed, reed cultivation, crab cultivation, sheep rearing and kewara cultivation and in drought condition, sheep rearing for ethnic minorities were the main livelihood adaptation options.

Hydroponics

In waterlogging area, hydroponics was proved as one of the sustainable agriculture for vegetable productions, which increased the capacity of the poor and marginal peasants. 40 participants were trained by the project and ten participants were observed practicing the hydroponics after 1 year of the project. The cultivation process is very much environment friendly and without chemical fertilizer farmers were able to grow summer and winter vegetables. Ladies finger, Spinach (*Lalshak & Palang shak*) and seedling of Cabbage, Kohlrabi, Tomato Chili, and Cauliflower were cultivated in floating bed. This livelihood option has made farmers a new alternative to cope with long term flooding or waterlogging condition, which might be one of the impacts of climate change in flood plains. Each family got a grant of USD 50 as input and with additional household labours the each family has a cost of USD 75.

Charu-Making (Fish Trapper)

There were almost 40 beneficiaries who had no land and do not have other skills to alter their livelihoods. Ten of such beneficiaries were trained on making fish-trapper. This was suggested by the community and in their logic model it appeared that with pro-longed waterlogging, the crop agriculture is likely to shrink and opportunity will be more for fish cultivation and many people have to shift their occupation from farmer to fisher. There will be then increased demand of fish-trap mostly in open water fisheries. In both sea level and waterlogging context there will be necessity of more fish traps and the trained landless people can maintain income wellbeing with this alternative means of livelihood.

Ring-Based Vegetable Cultivation

Ring-based vegetable cultivation in water logged area was a new concept, where vegetables were cultivated round the year. Concrete rings are placed in a relatively higher land around the homesteads and soils are filled up, then seeds are sown. When they grow, branches are put on structures made of sticks or bamboo poles, or they are put on tin/leaf roofs. Pumpkin, Gourd, Spinach, Chili, Balsam Apple, and other vegetables are cultivated in the ring-based system. The land is usually inundated all the time and there vegetable productions are obstacle. To combat the situation, this small solution have helped them go get some soil above the water level by putting the soil in the middle ring putting a small piece of wood or polythene cover to protect soil moisture from flood water. The project piloted this adaptation means to ten families only and all of the families have found economic benefits of it. Each family was provided 20 rings, seeds and some soil as grant from the project, which costs USD 32 for each family and benefits USD 56 as return.

Duck Rearing

Duck is a livestock bird animal. It inhabits on both land and water. The suitable areas for duck rearing are water logged areas and in open/closed water bodies. Duck rearing was the source of income in poor community for meeting their nutritional requirements specially proteins. The variety of duck is *kambel*, *indigenous* and *Runner.* A total of ten households were supported for duck rearing to combat income vulnerability to flooding and water-logging context. This was identified by the vulnerable households as they could not rear chicken in a recurrent flooding in their area and assumed that duck could have been a better resilient species to the flooding. Each household was supported with 25 pieces of duck with a total cost of USD 50 with additional 15 dollar support for 4 months feedings before producing egg. At the end, this was agreed with the local government that there is lots of scope to increase duck rearing in waterlogging and flooding context, because huge areas in southwest Bangladesh remain under water or water logged. On the other hand, due to climate change, sea level will rise is very likely to occur and poor households needs to adapt to the impact and duck rearing in southwest could be a better alternative.

Reed Cultivation

The prawn cultivation is a traditional practice in the coastal region of Bangladesh. But the landless poor have no option to cultivate prawn. In addition, water logging and salinity, swampy lands were available in the project area. These kinds of lands are not suitable for normal paddy cultivation. In these circumstances, reed cultivation practice was introduced by the local people at least 30 years before the project worked there. The project has further supported ten households with improved varieties, support in training and technology transfer at farmers' level: seed preservation, storage and farmer–farmer distribution. This was an alternative livelihood for the poor in the saline-prone area. USD 65 was the support per household.

Mat Weaving by Reed

Reed cultivation and weaving of mat is a nontraditional product and is very significant for the livelihood of the poor today in coastal areas. During the project period one skill development training on mat weaving was conducted among the vulnerable women. Later, the project supported ten beneficiaries for mat weaving. Each family was provided USD 40 for initial capital from the project and 15 USD to enable them with a suitable place for weaving in their dwelling house.

Kewra Tree Plantation

The Kewra (*Sonneratia apetala*) plants are usually cultivated on saline soil or around the ridges of a prawn culture area or in the premises of homesteads. In the project, Kewra plants were cultivated near the river beach. The Kewra is used for multiple purposes. Its fruit is edible by humans and can be converted to various food items. It has an economic importance for additional income to the poor. Side by side, it acts as an environmental protector, such as wind-breaks and soil protector against erosion in the coastal region. In addition, tree roots and shell of the fruits are used as fuel and its wood makes good furniture. There are three demonstrations of Kewra cultivation, implemented in Protapnagar Union of Assasuni Upazila. This was not a household activity but planted at community level linking ten beneficiaries with this project with an understanding that in future the households will use the fruits and branches of the tree for their domestic purpose.

Crab Cultivation

The pattern of the land use is changing in the coastal areas gradually. The causes are sea level rise and decrease of fresh water flow from the upstream at dry season. So it was necessary for the community to find out options for adaptation. At the same time, some adaptive measures should be evolved to increase the resilience to withstand disaster and climate change impacts of the community. During the project period, skill development training on crab fattening was conducted. The project budget allocated USD 600 for three demonstrations. The trained-up beneficiaries successfully completed crab fattening in six cycles totaling 9,000 crabs and earned a net profit of USD 4,000 in a year. A production cycle required a full lunar period (12–15 days). The production has inspired other vulnerable peasants in the community.

Sheep Rearing

Sheep rearing also was an important source of income as well as meeting the nutritional requirements specially proteins for vulnerable households in salinity and drought prone areas. In drought prone area, sheep rearing was suitable for the landless women and indigenous people. Sheep rearing was also an alternative source to increase family income. Each family was provided two sheep's by the project which cost USD 30 and other USD 5 for vaccination and medicines.

We have analyzed all these options from cost benefit, empowerment, equity, environmental, socio-cultural and technical (adaptation) perspectives. The analysis showed that all the projects will provide benefit at least 3 years. For Kewra cultivation, the tenure of the benefits of intervention will be more than 30 years. Table 18.1 shows the result of the multi-criteria analysis of the adaptation interventions.

The analysis shows that considering all criteria, for the community ring based vegetable, mat weaving, duck rearing and sheep rearing will be more feasible than other options. Interestingly, these options were women focused and therefore, gender dimension is also very important and meaningful aspect in taking decision about adaptation options. The project started with a climate risk assessment process in a participatory way followed by local adaptation action plan in each local government institutions and some pilot actions on adaptive livelihood practices. These results were documented and presented to different stakeholders at national and local level. The overall methodology and process of the project is shown in Fig. 18.1.

Table 18.1 Multi criteria analysis of climate change adaptation options at after 3 years

	Adaptation option								
Criteria	Hydroponics	Ring based cultivation	Duck rearing	Charu making	Mat weaving	Reed cultivation	Kewra cultivation	Crab fattening	Sheep rearing
Economic cost–benefit indicators (30)	15	30	30	30	30	30	–30	30	30
Social impact indicators (10)	5	5	5	5	10	5	10	10	10
Culture sensitivity indicators (10)	5	10	10	10	10	5	10	0	5
Gender sensitivity indicators (10)	5	10	5	10	10	0	5	0	5
Empowerment sensitivity indicators (10)	5	5	5	5	10	0	0	5	10
Environmental indicators (15)	–7.5	7.5	7.5	–7.5	0	0	15	–7.5	0
Labor and technological indicators (15)	10	15	15	10	10	10	15	5	15
Total weighted value	37.5	82.5	77.5	62.5	80	50	25	42.5	75

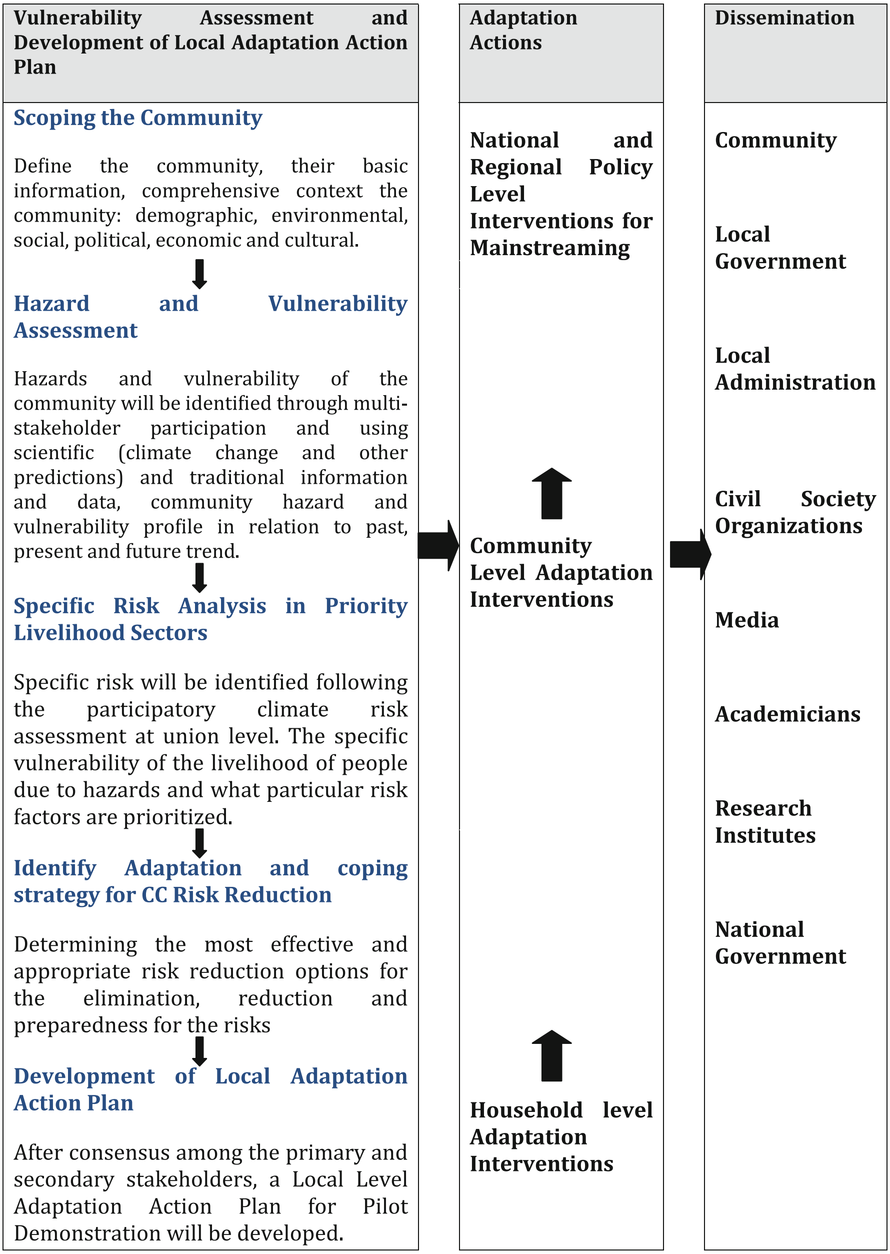


Fig. 18.1 Methodology of *Participatory Climate Risk Assessment and Development of Local Adaptation Action Plan* Project

18.2.2 Case-2: Reducing Vulnerability to Climate Change (RVCC) Project of CARE Bangladesh

The Reducing Vulnerability to Climate Change (RVCC) Project was the first initiative of its kind in Bangladesh. It was a 3-year project started in January 2002 and completed in March 2005. The RVCC project was funded by the Canadian International Development Agency (CIDA) and implemented by CARE Canada via CARE Bangladesh. The RVCC Project was implemented in six districts in southwestern Bangladesh—Bagerhat, Gopalganj, Jessore, Khulna, Narail and Satkhira—through partnerships with local organizations and communities. The project goal was to increase the capacity of Bangladeshi communities in the southwest to adapt to the adverse effects of climate change. The Project has been designed to assist Bangladesh, a non-Annex 1 country, to adapt to the impacts of adverse climate change via the promotion of sustainable development and the building of local-level capacity to advocate on climate change issues. The project worked with communities and institutions to raise awareness on climate change, adapt to environmental changes that could be exacerbated by climate change, and influence relevant policy.

The project worked at four levels:

Household Level: The project worked with 4,300 vulnerable households to build their capacity to adapt to climate change impacts by making them aware of new livelihood strategies, using a group-based approach.

Community Level: The project also worked with 14 Union Parishads (lowest tier of elected government) and community leaders to increase their awareness of climate change impacts and to develop and implement community-level adaptation strategies. The assumption was that community based action will support and add value to the household level actions.

Institutional Level: The project is supporting the capacity building of six local organizations in four areas: collection and dissemination of information, advocacy on salinity and its impact on potable water, awareness campaigns on climate change issues, and impart class lessons on 8-session module on climate change within the secondary school system.

National Level: Project partners are interacting regularly with national-level climate change stakeholders on policy advocacy issues in order to increase awareness of local climate change implications and local people's needs.

Here we will discuss only RVCC's focus on building capacity to undertake concrete actions to reduce vulnerability at the household and community levels.

Household-level Activities: The RVCC approach at the household level consisted of building the capacity of beneficiaries to cope with a particular vulnerability context as it impacts on a specific indicator of household well-being. The well-being indicators and vulnerability contexts were chosen on the basis of a participatory vulnerability assessment that was conducted early in the project, and has been refined, as field realities have emerged. The vulnerability contexts identified were: salinity, flood, storm, waterlogging, drought, cyclone and loss of biodiversity. The project attempted to address the impacts of these vulnerability contexts on the well-being indicators of income, food, housing, health and potable water.

In order to address specific combinations of vulnerability contexts and well-being indicators, a number of strategies had been identified:

1. Increase food through agriculture
2. Increase income through alternative livelihoods
3. Increase food availability/storage
4. Improve health and personal safety
5. Increase access to safe water
6. Improve safety of housing and other property

Within these strategies, different adaptation measures were selected for implementation based on the needs of grassroots people vulnerable to current climate related complexities, and the experience of the partner NGOs in the project area. Measures being piloted include: drought-resistant crops, floating gardens, duck and poultry rearing, rainwater harvesting, cottage industries, introduction of portable cooking stoves and flood-proof food storage, and storm-resistant housing, among others. In addition to promotion of adaptation measures at the household level, activities to market the products produced through agriculture and livelihoods measures were undertaken, along with research activities on hydroponics and waterlogging/flood tolerant rice varieties.

Community-level Interventions: Two community-level adaptation strategies, and corresponding measures, were identified to complement the work done at the household level. The community level strategies were to:

1. Increase access to common property resources
2. Reduce threats through community-based initiatives

Access to common property was identified as a need for landless beneficiaries in order to implement measures under the agriculture and livelihoods strategies. Activities under this strategy supported local-level advocacy to ensure rightful access to these resources by beneficiaries. For reducing threats at the community level, the project worked with Union Parishad (UP) chairs, members and community leaders to build their capacity to plan and implement community-level measures that will reduce threats from the vulnerability contexts of flood, salinity, cyclone and waterlogging. The measures promoted include Tidal River Management (TRM), raising embankments, cyclone shelters and canal excavation. Implementation of the measures to reduce threats was not within the scope and resources of the RVCC project, however the aim was that each UP will develop an action plan for the measure within the project's lifetime.

18.2.2.1 Process of Designing RVCC Actions for CBA

Vulnerability Assessment: The project begins with a vulnerability assessment through a participatory process. Following the Participatory Rural Appraisal (Chambers 1983, 1992), the project has identified 48 different aspects in their livelihood conditions that made them vulnerable in their efforts to improve or even maintain their present level of well-being. These aspects were related both to events beyond their control (such as cyclones and death of a family member) and to shortcomings in their capacity to cope with these events. In other words the 48 vulnerability aspects reflected both where these people were vulnerable to (Vulnerability Context) and why they were vulnerable (i.e. lack of coping capacity).

The project selected only 28 vulnerability aspects out of the 48 identified, at 25 % of the community people were exposed to the aspects. The project further reduced the 28 selected vulnerability aspects to 17 focusing on climate change related vulnerability contexts. Table 18.2 gives an overview.

The project then tried to identify the adaptation strategies and select a few strategies for piloting. The measures were considered to ensure the strategy and the strategies were very much linked to reduce the vulnerability to climate change. The following selected activities (Table 18.3) were implemented and tested by the RCVV for each of the eight strategies. The final selection and specification of these activities was "dictated" to an important degree by the experience of the local partners of the project and the specific context they are working in. In a long process, the local partners specified the activities they would undertake, based on their knowledge and experience and responding to the need of the project to address the issues of reducing vulnerabilities to climate change. In practical terms this implied that awareness building activities have been skipped as much as possible and that community-focused activities were promoted.

In several aspects, the RVCC Project was a pilot initiative and first of its nature in Bangladesh. This did not only refer to its subject: adaptation to climate change at the field level, but also to the participatory approach facilitated by local non state actors. This was not recognized sufficiently at the beginning. A range of cost benefit analysis, post project vulnerability matrix and lessons learned document demonstrate that there was huge potential to scale up this pilot project and many CBA intervention after 2004 followed the methodology if this project. There is ample evidence that the RVCC project has contributed to the improvement of the capacity of vulnerable households to innovate their livelihood strategies, and thereby reduce their vulnerability to climate change. The various methods (awareness raising, training modules, learning sessions, cross visits, demonstration plots, individual follow-up, etc.) appear to have been very effective.

Table 18.2 Effects of selected climate change-affected vulnerability contexts on five securities (well-being indicators) (%)

			Well-being indicators/insecurities														
			Income			Food			Housing			Health			Potable water		
SL #	Vulnerability contexts		M	F	Mix	M	F	Mix	M	F	Mix	M	F	Mix	M	F	Mix
1	Salinity	Category 1	27	25	31	21	25	30	12	10	7	14	14	19	3	5	0
2	Flood		25	22	23	18	18	14	16	17	21	11	12	13	3	3	4
3	Water logging		27	29	23	21	24	19	6	10	16	16	16	13	2	0	0
4	Drought	Category 2	26	32	27	26	23	32	6	5	2	16	16	19	3	4	4
5	Siltation		27	30	30	19	20	37	11	14	8	9	11	6	4	0	0
6	Water and insect borne disease		20	28	26	12	18	23	1	4	3	24	20	29	6	0	0
7	Wind/storm		20	22	35	20	19	37	21	19	11	11	12	0	0	3	0
8	Loss of bio-diversity		27	23	43	22	21	27	9	5	8	15	19	11	3	2	0
9	Heavy rain		27	25	25	19	22	28	13	14	11	9	10	7	3	3	0
10	Arsenic problem		24	22	10	24	24	31	0	10	0	37	20	50	0	0	0
11	Cyclone		22	22	26	15	20	21	20	21	16	11	10	5	5	3	3
12	River erosion		20	22	20	15	16	20	6	9	10	6	5	8	2	2	0
13	Price fluctuation		27	31	24	23	19	24	14	3	7	8	15	10	0	0	5
14	Malnutrition		43	40	10	22	30	30	5	5	4	16	15	46	0	0	0
15	Land use pattern		30	42	45	30	28	15	10	10	5	10	14	25	0	0	0
16	Shrimp farming		42	24	0	10	21	0	15	8	0	6	17	0	6	6	0
17	Death of earning member		35	30	25	19	18	9	6	13	18	13	13	9	0	0	3

Source: CARE (2002a, b, c)

Table 18.3 Overview of strategies, measures and activities selected for implementation

Strategy	Measure/type of activity	Vulnerability context
Increase food and income through agriculture	Floating garden technology	Waterlogging
	Saline tolerant non-rice crops	Salinity
	Drought tolerant crops (BCA)	Drought
	Homestead vegetation	Salinity; flood
Increase income through alternative livelihoods	Mele (reed) cultivation	Salinity
	Saline tolerant tree plantation	Salinity
	Forestry (nursery and homestead afforestation)	Salinity, drought, waterlogging
	Embankment cropping	Tidal flood
	Fish and poly fish cultures	Waterlogging; tidal flood
	Cage-aquaculture	Salinity, waterlogging
	Crab fattening	Salinity, tidal flood
	Poultry and duck rearing	Salinity, waterlogging, tidal flood
	Safe havens for domestic birds and animals	Tidal flood
	Livestock rearing	Tidal flood, salinity, waterlogging, drought
	Apiculture and honey processing	Loss of biodiversity
	Production and marketing of handicrafts	Salinity, flood
	Marketing skills	Waterlogging, flood
Increase income through access to common property resources	Access to common property regimes within the waterlogged areas	Waterlogging
	Establishing rights to government khas land for various community activities	Flood
Increase availability of food	Food storage	Flood
	Cooking stoves	Flood
Improve health conditions and personal safety	Hygiene and sanitation	Flood, waterlogging
	Protection against cyclones	Cyclone
Improve access to safe water	Awareness on safe water	Flood; salinity
	Rainwater harvesting and storage	Salinity
	Small protected pond at hh level	Salinity
	Community based pond sand filter	Salinity
	Indigenous methods of getting pure and fresh water	Salinity
	Deep tube wells	Salinity
Improve safety of housing	Storm resistant housing	Storm
	Wind breaks around dwellings (i.e., houses and community buildings/facilities)	Storm
Reduce threats	Waterlogging	
	Droughts and salinity	
	Salinity	
	Cyclones	
	Floods	

18.3 Community Based Adaptation: Common Elements and Characteristics

In earlier sections, we have discussed about the theoretical underpinnings of the community based approach, where community based adaptation is also equally applicable under the theoretical framework. Later we discussed about two case projects in Bangladesh. Now, we will synthesize our discussion to draw some common inferences for outlining some common features of CBA.

1. **People Centered**: The first common features and element of a CBA is that the programme has to be essentially people centered. This might seems very anthropocentric, but for a CBA, this is a fundamental building block. We have seen that in both the case studies, people were the center of the programme. Both the programmes tried to develop such methodology so that they can work with most vulnerable and people at risk that has highest need. Keeping human being in centre, the CBA, emphasize that whole other investment is for human being, if the investment cannot give benefits to the people, with any climate fiancé adaptation is very unlikely to happen. CARE (2010) has offered a CBA framework focusing on four elements: promotion of climate resilient livelihoods strategies, disaster risk reduction strategies to reduce the impact of hazards on vulnerable households, capacity development of local civil society and governmental institutions, and advocacy and social mobilization to address the underlying causes of vulnerabilities. If we see the all four elements of its CBA framework, these all are people centered. However, others (Haq 2008; Heltberg et al. 2011; Bettina and Annecke 2010; Ensor et al. 2002; IISD 2010) also implicitly highlighted the people centrism as basic characteristics of CBA. The following aspects could be synthesized from the literatures (ibid).
   (a) Focus on human and social vulnerability to climate change
   (b) Focus on human adaptability
   (c) Treat different technology or adaptation options as mere means for human being to adapt to climate change, the options or practices are not adaptation itself
   (d) People's point of view is basis for setting priorities
   (e) Decision about means and technology is the key responsibility of human being suffering with climate change induced impact events
   (f) People is the center of the evaluation and rely on people's ability is fundamental
2. **Process Dominated**: Adaptation is a very old phenomenon, when the term is used to adapt to climate or weather. This means then the change scenario is less dynamic and a bit fixed for a certain period of time. However, adaptation to climate change is different than the historical climate adaptation. When the change is dynamic, non-linear and to some extent unpredictable, though certain but with this uncertain change context, adaptation is very unlikely to be grasp as an outcome and hard to measure. This is therefore quite different from other

community based programme. In CBA, for this unique context, the process have become very important and an important building block for a success. Often we therefore ended with "adaptive capacity" instead of "adaptation" as a right phenomenon (Adger et al. 2007). Adaptation practices is therefore attempt to actual adjustment or changes in decision environment (Adger et al. 2007). The assumption is such adjustment will lead to a higher degree of resilience of the element at risk in dynamic climate change impacts. If we now consider, the inherent people's point of view in the adaptation, inevitably it will predominantly focus on a process that will help a vulnerable community to do persistent actual adjustment to the dynamic nature of the impacts of climate change in future. Taking notes from the two case projects in Bangladesh, and the CARE (2010)'s CBA toolkit, we can propose the following aspects in the "Process" element of CBA.

(a) Participatory is the key process to CBA.
(b) Informed decision making process is important, as many climate change risk are unknown to community members and needs information from scientist (Rashid and Islam 2006).
(c) When change is dynamic, actual outcome is rather impossible, focus on process for continuous learning and adaptive capacity is key then
(d) Process is important for community ownership, shared responsibility and future oriented actions. This helps to see adaptation is a continuous add on process to respond to the dynamic pattern of climate change impacts.
(e) Collective and Inclusive decision making process is important, as the climate change is long term and most of the community based programme cannot plan for 30–50 years spectrum. The collective decision of scientific community and local people is therefore very much inevitable and such partnership is fundamental to make the process towards resilience. Similarly, inclusion approach is very much important as the increasing economic and social inequality might create more vulnerability and might make the climate change impact worst if we do not meet the differentia needs of the different vulnerable groups into an inclusive and participatory decision making process at community, when doing CBA.

3. **Community Based/Community Led**: The idea of community based approach is debatable with climate change adaptation issues. Other than CBA, most community based programme is designed to use community resources, community knowledge, community institutions and community leaders to design, implement, monitoring and assess the programme. In case of Climate Change Adaptation, the fund is not necessarily to be local and from community. The community has become compelled to adapt to climate change and historical responsibilities lies with big polluting developed and developing countries. Therefore, in climate change adaptation, not necessarily financial resource has to be local. This distinction urges that the adaptation programme at community level could be termed as "community led adaptation". The leadership should be with community, who is likely to adapt and large portion of resource should come from outside community as historical commitment from industrial countries. Other than this small difference, community base or community led is vital. The key essence is that

community organization should be the key entry point for designing the CBA programme. Communities own institutions, culture, coherence, human resources, political will and other capabilities will be the basis for CBA to reduce the vulnerability of the people likely to be exposed to the climate change impacts (Rashid and Islam 2006). The following aspects or issues are important for ensuring the community based or community led characteristics to achieve in CBA.

(a) Community Organization and Institution should be the base for CBA service delivery
(b) Organizational culture is the key factor of governing the community based adaptation programme
(c) Community's own knowledge, skills, resources and capacities will be the basis to build on the adaptive capacity
(d) Community's leadership is key to drive the CBA programme
(e) Community's institutions are key to be the partner for most possible works in CBA

4. **Knowledge Oriented**: Most of the CBA programme basically starts from this characteristic. In different CBA practices (Haq 2008; Heltberg et al. 2011; Bettina and Annecke 2010; Ensor et al. 2002; IISD 2010; CARE 2010), and in the two case studies, we have seen that most of the CBA programme starts with risk assessment. The climate change risk is new and dynamic; therefore, the risk assessment is important. In most of the communities, climate change impact information is very much impossible to get locally. Community has to rely on scientists to have that information. In all the programme and toolkits, even in the two case projects, the technical people and outside facilitators has conducted the risk assessment and informed the community members during the priority exercises. This is not the normative practice in community based approach, though most community based assessments are done by external people than the community but for a good CBA programme, the assessment lead should go to the local people, external people will provide information based on scientific research. If the community feels strongly that there is a need of risk information from scientists, and they want to examine that information with their experience should be encouraging elements in a CBA programme. Community should collect information, blending the scientific information with their experience will generate knowledge and understanding and then create solutions and do pilot actions and also conduct own investigations along with external support to create new knowledge on adaptation. Education institutions, youth clubs and some other educated community members can also be involved in such process. This will be then helpful for the community to get a quick and capable partner at community for risk and risk adaptation knowledge in their own community. The following issues are important in characterizing the knowledge oriented community for adaptation.

(a) New knowledge is important for risk assessment and adaptation, as the issues are much uncertain than to get from the historical trend analysis from past experiences.

(b) Creation, utilization and dissemination of knowledge is important for the community. The ownership of all research including very scientific research should be placed at community or any of its institutions for further uses and updating.
(c) Learning is the key driver of change towards resilience journey. Community should have more opportunity to learn from CBA and continuously be innovative and application of the lessons into next innovations.
(d) Formal and informal both ways of knowledge management is important.
(e) Building community's knowledge hub is important.
(f) A knowledge society is fundamental for CBA.

5. **Empowerment Focused**: The CBA programme has to be empowerment focused. Entitlement, deprivation, human rights, governance and justice are the key sub-building blocks for an empowered community to run a CBA programme. Empowerment will achieve if we can make the people confident on their own ability to do the CBA: diagnosing the problem, find out the right solutions from range of alternatives and being able to implement with minimum technical but huge financial support (only in case of adaptation) to face the climate change risks (Rashid and Islam 2006). This is a critical aspects in CBA different from other community based approaches. In this CBA, funding is mostly external and therefore risk is high for a less empowerment process in implementing the CBA. Therefore, we need to ensure that finance as donation is important and a legitimate right under global climate justice framework but often very powerful itself to destroy the community's empowerment and pride. Therefore, following issues need to take care during designing a CBA programme.

   (a) Confidence on knowledge, skill, capacity, resources is key
   (b) Political and economic decisions can be taken by community despite the sources of money
   (c) Ability to make other accountable is a key power to bring benefits for community
   (d) Empower others when decision has to be collective
   (e) More democratic and enabling in tolerate diversified opinion
   (f) Rely most on own resources
   (g) Entitlement of climate change victim is highly respected, valued and realized

6. **Accountability Driven**: Accountability is one of the important building block in a CBA programme. This has to be ensured that the CBA programme is totally accountable to the beneficiaries and other stakeholders. The CBA programme has to ensure that the community can participate in designing their own monitoring indicators to capture the progress the CBA projects. This is the last building block of the CBA programme. The following issues are very important during designing the accountability aspects of the CBA.

   (a) Is accountable to the constituency
   (b) CBA planning, implementation and monitoring system is participatory and transparent

(c) Ensure both downward and upward accountability
(d) Share responsibility and rights with community members
(e) Make other's accountable to the community

18.4 Conclusion

In the whole discussion in last three sub-sections, this is apparent that Community Based Adaptation is a very promising area of investigation in terms of community based development paradigm. The CBA might contribute a lot in the overall community development approach as the CBA is in many terms unique than usual community based programme. This is also true that CBA has not just emerged from the sky and we have discussed the clear historical genesis of community based approaches and CBA's fits into those broader approaches. The differences in CBA might be further area of investigation to develop theories in community based adaptation. The discussion also highlighted that an opportunity in developing a theory is very likely as the practices are now very wide spread and we have also a long history of community based disaster preparedness programme, which is very closely connected with community based adaption programme. Bangladesh is unique in many cases; but for climate change this country is not only unique but also a field laboratory and knowledge hub for global adaptation practitioners. The two case projects that we have discussed have provided a solid methodological niche for CBA. The both practices are highly regarded in Bangladesh an international forum. The two case studies and other practices in Africa has also helped us to unpack a set of CBA programme features, which are not steps of designing CBA programme, rather provide a clear philosophical, methodological and theoretical basis for CBA. These features are discussed to welcome more debate and inputs towards such issues and need to develop an universally accepted theory and methodology for CBA for at least a decade.

References

Adger WN, Agrawala S, Mirza MMQ, Conde C, O'Brien K, Pulhin J, Pulwarty R, Smith B, Takshi K (2007) Assessment of adaptation practices, options, constraints and capacity. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts adaptation and vulnerability. Contribution of working group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp 717–743

Bettina K, Annecke W (2010) Community based climate change adaptation (CBA). Adaptation and Beyond Issue I (www.indigo-dc.org)

CARE Bangladesh (2002a) Project Implementation Report (PIP) of RVCC Project. CARE, Dhaka

CARE Bangladesh (2002b) Knowledge, attitude and behavior (KAB) Report. CARE, Dhaka

CARE Bangladesh (2002c) Vulnerability Assessment Report for RVCC Project. CARE, Dhaka

CARE (2010) Community based adaptation toolkit. CARE, Merrifield VA

Chambers R (1983) Rural development: putting the first last. Longman, London
Chambers R (1992) Rural appraisal: rapid, relaxed and participatory. IDS Discussion Paper 311: Brighton
Escobar A (1995) Encountering development: the making and unmaking of the Third World. Princeton University Press, Princeton
Freire P (2000) Pedagogy of the oppressed. Continuum Press, New York (originally published in 1970)
Gandhi MK (1962) Village Swaraj. Navjivan Press, Ahmedabad
Haq S (2008) Community based adaptation. Tiempo. Issue 68 http://www.tiempocyberclimate.org
Heltberg R, Gitay H, Prabhu RG (2011) Community-based adaptation: lessons from a grant competition. Clim Pol. doi:10.1080/14693062.2011.582344
IISD (2010) Community Based Adaptation to Climate Change Bulletin, 135(3). In: A summary of the forth international conference on Community Based Adaptation to Climate Change
Malinowski B (1922) Argonauts of the Western Pacific. George Routledge and Sons, Limited, London
Nilson P (2006) The theory of community based health and safety programs: a critical examination. Ini Prev 12(3):140–145
Rashid AKMM, Islam MTU (2006) Community risk assessment: an integrated etic and emic approaches to asses hazards and vulnerabilities. In: Amman WJ, Haig J, Huovinen C, Stocker M (eds) International disaster reduction conference, Part 2 extended abstracts
Schumacher EF (1973) Small is beautiful: economics as if people mattered. Blond and Briggs, London
Scott, James (1998) Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed. New Haven, Conn.: Yale University Press
Sobranie Sochinenii NN (1950) Miklоucho-Maclay, vols I–IV. Moscow Academy of Sciences. Miscellaneous Papers vol I & II. Mitchell Library, Sydney
White, Howard (1999) Dollars, dialogue and development. An evaluation of Swedish programme aid. Sida Evaluation 99/17. Stockholm: Swedish International Development Cooperation Agency

Part V
Climate Change Governance

Chapter 19
Bangladesh Climate Public Expenditure and Institutional Review

Mark O'Donnell, A.K.M. Mamunur Rashid, Paul Steele, Merylyn Hedger, Joyce Lee, K.M. Nabiul Islam, Tawhidul Islam, Rezai Karim Khondker, Siddiqur Rahman, Dipak Kumar Sarkar, and Narayan Chandra Sinha

Abstract Bangladesh has a long history of, and substantial expertise in, managing response to Climate Variability and Natural Disasters pre-dating the emergence of Climate Change as a policy arena. Climate Change response in Bangladesh is a complex, multi-sector, multi-stakeholder undertaking that budgets and spends around US$1 billion per year through Government and Donor funding. In 2012 the General Economics Division (GED) of the Planning Commission, sponsored by the UNDP and UNEP, commissioned and undertook a Climate Public Expenditure and Institutional Review (CPEIR) with the objective of analysing this spend, its policy and strategic drivers, the institutions delivering it and sought ways how this could be managed more effectively. The study revealed the key conclusions based on the

---

M. O'Donnell • A.K.M.M. Rashid (✉) • M. Hedger • J. Lee
PECM (Poverty Environment and Climate Mainstreaming) Project,
UNDP Bangladesh, Dhaka, Bangladesh

Department of anthropology in Jahangirnagar University, Dhaka
e-mail: nemoibsru@gmail.com

P. Steele
UNDP Regional Office, Bangkok, Thailand

K.M.N. Islam
BIDS, Dhaka, Bangladesh

T. Islam
Department of Geography, Jahangirnagar University, Dhaka, Bangladesh

R.K. Khondker
Department of Economics, Independent University of Bangladesh, Dhaka, Bangladesh

S. Rahman
Department of Anthropology, Jahangirnagar University, Dhaka, Bangladesh

D.K. Sarkar
Budget Monitoring Unit, Bangladesh National Parliament Secretariat, Dhaka, Bangladesh

N.C. Sinha
Finance Division, Government of Bangladesh, Dhaka, Bangladesh

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*,
Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_19,

review and identified that the government is the main funder of the Public Sector response to Climate Change and climate sensitive activity with around 75 % of funding coming from domestic sources on an annual basis. The government response is firmly embedded in existing institutions and policy frameworks and there are a number of new mechanisms being established by both Donors and Government which have yet to deliver substantial numbers and values of expenditure. There is evidence of that Climate Change Strategy has not fully penetrated the sector policy drivers of budget execution resulting in a need for improved co-ordination and profile mechanisms at Central Ministry level. There is an extraordinarily diverse range of administrative agencies involved in budget execution of climate sensitive expenditure. There is evidence that duplication and omission of activity are significant risks to the optimisation of climate response due to the diversity of institutions involved. A "gearing effect" may be evident within funding climate change actions in Bangladesh. It was noted that an increase of 11 % in donor commitments and an 18 % increase in Government commitments occurred simultaneously. It may be that there is causation between the two. The CPEIR study recommended that the way forward in Bangladesh is to introduce greater rationality in establishing the economic position and impacts of government expenditure through a macro-economic study with a view to identifying private sector partnerships in climate response, establish medium and long term costed response plans for incorporation into budgets, clarify intuitional mandates with a view to developing appropriate specialisation in climate response, and strengthen existing (and beleaguered) government co-ordination, resource allocation, monitoring and classification arrangements in Planning and Finance.

Keywords Climate finance • Climate public expenditure • Institutional review • Public expenditure

19.1 Climate Public Expenditure Review

This Climate Public Expenditure and Institutional Review (CPEIR) is an analysis of the policy, institutional and financial management arrangements of the agencies involved in climate sensitive activity in Bangladesh focused mainly on Government—both central and local government. The analysis is done based on an adopted methodology to identify and assess the financial scale of climate sensitive activity carried out by the Government. This methodology was applied to generate initial indicative figures and analysis of budgets and spend from the past 3 financial years. The figures were set in a national context by comparing the budgets and spend to both GDP and the Government budget as a whole. Public Financial Management systems were also reviewed (World Bank 2010a, b, c). Analyses of the international arrangements for financing climate actions, the current roles of NGOs, the private sector and households in Bangladesh were also considered.

In summary, the CPEIR comprised an assessment of current policy priorities and strategies as these relate to climate change at national and local levels, a review of the institutional arrangements for promoting the integration of climate change policy priorities into budgeting and expenditure management, and a review of the integration of climate change objectives within the budgetary process including as part of budget planning, implementation, expenditure management and financing.

19.1.1 Challenges of Public Expenditure Review for Climate Change

Climate change itself is not easy to define for economic or financial assessment and it is also a relatively new entrant to the public policy arena. Identification of spend is therefore the first challenge. There are two distinct aspects to this challenge.

Firstly, there is no functional classification in the standard of classification for expenditure (COFOG in GFSM 2001) therefore it is easy to be drawn to an administrative approach to identifying climate spend—that is, an approach based on which administrative unit spends money (IMF 2001, 2011). This limitation was exposed by the cross cutting and diverse nature of the response to climate issues ranging from hard adaptation capital works to socially based protection, livelihoods and health programmes that form the adaptation strategies of government. The term "climate" rarely features in the descriptions of administrative units responsible for delivering adaptations (Asian Tiger Capital Partners 2010; Ayers et al. 2009; Burton 2004).

Secondly, the separation of climate sensitive spend and climate change spend is a qualitative and judgment-led exercise and is open to refinement and constructive criticism. Equally, there is valid debates to be conducted on the separate classification of climate resilience spend, from development deficit spend and which element of expenditure addresses each component (Hedger 2011; Haque 2009).

These are complex matters which at this stage of analysis of climate sensitive spend that arise because climate response and therefore climate change expertise is firmly embedded, on the whole, in existing institutions, activities and policy frameworks, but is not always explicitly recognised as such. This could be, however, regarded as a rational state of affairs as charging technically able, legally mandated national experts (all other things being equal) with managing response is most likely to result in the most effective outcomes (Tanner and Mitchell 2008; Stadelmann et al. 2010).

The study, as an initial rather than a definitive snapshot, expressed the hope that it would contribute to the framing and identifying future research. The methodology developed in the study is a first step in what is expected to be an ongoing process of refinement, review and evaluation of climate expenditure in Bangladesh and elsewhere.

Table 19.1 Defining climate change

Mitigation	
OECD Definition: An activity should be classified as climate change mitigation related if it contributes to the objectives of stabilisation of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system by promoting efforts to reduce or limit GHG emissions or to enhance GHG sequestration (OECD 2011)	
Sector	***Example activities***
Forestry	Protection and enhancement of sinks and reservoirs of GHGs through sustainable forest management, afforestation and reforestation
Water and sanitation	Methane emission reductions through waste management or sewage treatment
Energy Transport Industry Agriculture	GHG emission reductions or stabilisation in the energy, transport, industry and agricultural sectors through application of new and renewable forms of energy, measures to improve the energy efficiency of existing machinery or demand side management (e.g. education and training)
Adaptation	
OECD Definition: An activity should be classified as adaptation-related if it intends to reduce the vulnerability of human or natural systems to the impacts of climate change and climate-related risks, by maintaining or increasing adaptive capacity and resilience (OECD 2011)	
Sector	***Example activities***
Enabling activities	Supporting the development of climate change adaptation-specific policies, programs and plans
Policy and legislation	Capacity strengthening of national institutions responsible for adaptation
Agriculture	Promoting diversified agricultural production to reduce climate risk
Energy	Strengthening of energy transmission and distribution infrastructure to cope with the expected impacts of climate change
Forestry	Securing local rights and systems for the sustainable and long-term utilisation of the forest in order to increase resilience to climate change
Health	Strengthening food safety regulations; developing or enhancing monitoring systems
Transport	Building protection from climate hazards into existing transport infrastructures (e.g. Disaster Risk Reduction measures)
Water and sanitation	Monitoring and management of hydrological and meteorological data

Source: OECD (2011)

19.1.2 Defining Climate Change

The definition of climate finance used in the CPEIR recognised that resilience to the effects of both climate and climate change is a multi dimensional activity—as outlined in the BCCSAP. In reviewing the climate sensitive budgets and expenditure, it was found that the scale, range and diversity of both budgets and the agencies involved in delivering activities that contribute to intended climate resilient outcomes for Bangladesh tends to suggest that developing a single definition would be a complex task (Alam et al. 2011; CCC 2007; COWI and IIED 2009; DMB 2010; DMRD 2008, 2010; GED 2010; GoB 2008; Hedger 2011; Huq and Rabbani 2011).

In conducting the analysis a working definition of Climate Sensitive expenditure was used that was based broadly on the OECD definition shown in Table 19.1. Defining Climate Change and related specifically to climate variables and impacts and how the government has responded to this. In essence the working definition used is based on the identification of adaptation activity with a linkage to the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) and its policy themes.

It should be noted that the analysis focused on the policy interventions needed for climate change adaptation, recognising the current priority in Government of Bangladesh (GoB) approaches to climate change (Huq and Rabbani 2011; Hedger 2011). However the CPEIR does highlight the considerable sums being invested in fossil fuel power generation, thus increasing greenhouse gas emissions, although these still remain very small on a global scale. This illustrates the policy dilemma that inevitably arises when considering economic development in Bangladesh. Essentially, industry needs power to drive economic growth and to achieve this. The Government has the allocative task of deciding the relative merits and imperatives of explicitly prioritising climate adaptation, climate mitigation or growth from the limited resources available. This also points up the need to have more knowledge of the macro-economic impact of climate sensitive spend to inform the debate (Narain et al. 2011).

19.2 Bangladesh Context: Climate Public Expenditure Review

In the Bangladesh context, it is well known that there are many agencies involved in climate response and climate sensitive activities including central and local government, development partners, NGOs, households and the private sector. Indeed, this has been characterised in the public domain as "institutionally chaotic" However, until the CPEIR was conducted, there had been no systematic review to identify the scale of the ongoing financial commitments, the scope of institution as involved or the key policy drivers in this aspect of public expenditure.

An expressed, key long term aim for the Government of Bangladesh is to develop a Climate Fiscal Framework within which the roles, risks, and responsibilities of parties involved in climate response can be allocated and a sustainable long term funding framework built.

19.2.1 Financial Review

The CPEIR analysed budgets and expenditure over a 3 year period from 2008/2009 to 2011/2012. The main focus was on the government budget. Among other matters the study reviewed the overall allocation of resources, the mechanisms delivering climate finance, the financing of climate spend, the main agencies involved, their processes and the nature of the budgets and the spend delivered. A methodology was also developed to identify climate finance within the Government budget. The methodology relied on qualitative and ultimately subjective judgements of spend as no universal international definition of climate change spend exists within COFOG or definitely elsewhere. This approach produced an indicative outcome in absolute terms and a similarly indicative, although informative, analysis of spend and climate actions undertaken by the government. The methodology was new and undoubtedly capable of further refinement under the scrutiny and evaluation of a wider audience. It is to be hoped that the study will form part of a dynamic process contributing to greater understanding and effectiveness of a climate response in Bangladesh (CPD 2008).

The CPEIR in Bangladesh compellingly demonstrates that climate change is a substantial, cross cutting, multi sectoral activity and that, comparing the response in Bangladesh with that of other countries is currently difficult as the precise definition and framework for each country is largely determined by that country. From a Government perspective—as perhaps evidenced by the institutional allocation of responsibility—the main issue is to deliver climate resilient development, covering current climate variability and climate change.

Amongst the important lessons learned from the review of budgets and expenditure is that expenditure typically contributes to more than a single outcome, often perceived as being readily identifiable by primary and other purposes. This was particularly evident in respect of Social Protection Schemes (BCCSAP Theme 1) where it was found that determining the climate and climate change-attributable element of these strategic initiatives was very much a matter of both perception and qualitative, informed but ultimately subjective judgements. This is also evident in physical adaptation work, for example, where the incremental or marginal expenditure relating to a change in climate is inextricably bound together with the design and implementation of the adaptation as a whole. The purpose of such activities will contribute to a number of outcomes including climate change resilience (BSS 2011, 2012).

This facet of identifying specific and singular climate change budgets and separating these from budgets intended to achieve other outcomes such as response to disasters as well as climate resilience would require a level of sophistication in budget classification and cost allocation that would perhaps elude most countries in the world and would certainly require substantial development of systems and capacity to achieve. It was found, however, in Bangladesh that substantial progress has been made in recent years in financial accounting and that financial data on a code by code basis over a number of years was readily available in flexible, specifiable formats for analysis (IMF 2011).

It should also be considered in the Bangladesh context that GoB has implemented many policies for climate variability and disaster risk management for many years and this activity pre-dates the emergence of climate change as an issue. These activities have contributed to strengthening the country's response to climate change concerns. This has, perhaps inevitably and for sound operational reasons, led to the situation where climate change budgets and expenditure are integrated with and integral to existing historical activity and institutions and cannot readily be separated from this. With this background in mind the main findings, conclusions and recommendations from the financial review the major findings are set out below.

Based on the methodology used in the study it is estimated that the Government of Bangladesh typically spend around 6–7 % of its annual combined (development and non-development) budget on climate sensitive activity. This equates to an annual sum in the region of US$1 billion at current exchange rates. This sum is utilised to address all six themes within the BCCSAP. However it is noted that whilst the spend on climate sensitive activity increased from 6.6 % to 7.2 % between 2009/2010 and 2010/2011, it fell back to 5.5 % of budget in 2011/2012.

This level of expenditure represents something in the region of 1.1 % of GDP on an annual basis. The financing of the annual spend is largely funded from domestic resources. Over the period 2009/2010 to 2011/2012 the funding of climate sensitive budgets has been of the order of 77 % from domestic resources and 23 % from foreign donor resources. This is broadly in line with overall funding of GoB expenditure (development and non development) overall which is funded approximately 80 % by domestic resources.

There has been a marked shift in the donor resources funding climate sensitive budgets in recent years from grants based to loans based. Loan funding increased from 58 % to 82 % of foreign resources between the 2009/2010 and 2011/2012 programmes. It was found that approximately 97 % of spend attributable to climate sensitive activities was for climate adaptation as classified under the BCCSAP themes ranging from infrastructure to social protection.

In absolute terms, the level of climate sensitive budget rose between 2009/2010 and 2011/2012, however, between 2010/2011 and 2011/2012 the absolute level of spend reduced. It seems likely that this was due to resources being diverted to energy and transport through the ADP. This presents a climate change dilemma for Bangladesh as the recently developed energy policy sets out to address the present reliance on Natural Gas for by increasing usage of fossil fuel as well as renewable sources. Bangladesh has significant quantities of high quality coal reserves and is presently developing a National Coal Policy (MoPEMR 2011; The Daily Star 2011).

An increase in overall climate related commitments by 16 % between 2009/2010 and 2011/2012 was driven by the non-development budget which is 100 % financed by GoB. GoB commitments increased by 18 % in the period whilst foreign resources increased by 11 %. This may be termed, in practice, a "gearing effect" at the macro level whereby increases in donor funding (specifically for the climate change element) have been met by a GoB increase in overall climate sensitive spend. Essentially, based on the figures in the study, a 10 % increase in donor funding delivered an outcome of 15 % increased spend in climate sensitive activities.

19.2.2 Public Financial Management

There are four main operational mechanisms in place to deliver climate sensitive spend at the time of writing. These are non development budget, annual development programme (ADP), Bangladesh Climate Change Trust Fund (BCCTF) with government funds, and Bangladesh Climate Change Resilience Fund (BCCRF) with donor funds (Polycarp 2010; GoB 2008).

All operational funding mechanisms address all six themes in the BCCSAP, albeit some specialisation was noted in that the non-development budget funds a larger proportion of the Social Protection theme and the ADP funds a greater proportion of infrastructure adaptation. This may be expected, given the capital intensive nature of infrastructure expenditure. However, perhaps the main point of concern is the risk of gaps and overlaps arising within what is a significant and complex annual undertaking. A further financing facility [Strategic Programme on Climate Resilience (SPCR)/Pilot Programme on Climate Resilience (PPCR)] is also coming on-stream in the near future thereby creating further risk of both "gap and overlap". Given this, there is a clear case for addressing co-ordination at the technical, financial and planning levels and perhaps even a case, after due consideration, for specialisation of funding streams.

It was found that most of the climate sensitive spend delivered is within multi-dimensional, strategic programmes, including the Agricultural Subsidy and Social Protection Programmes which are substantially funded through the non development budget. The study used a scale of direct relevance from "direct" or concrete adaptation through to implicitly relevant programmes on a scale of 1–4—i.e. implicitly or somewhat relevant. Around 70 % of the budget and spend was found to be within the level 3 and 4 programmes. Three things came out as a indicative to the public finance management.

Existing programmes, institutional and budget architecture are being utilised by the government to deliver climate sensitive activity, including responses to climate change. This is perhaps unsurprising given Bangladesh's long experience and accumulated expertise of response to climate variability and natural disaster. The separation of the climate change element of these programmes is a subjective and judgmental task given the evident integration of climate sensitive policy, institutions and budgets with pre-existing climate related structures in the Government systems. In terms of strengthening institutions through technical assistance and thereby supporting the delivery of climate sensitive spend, there is a clear case for focussing on country systems as this is where the most significant element of ongoing climate response, on a financial technical and experience basis, is located.

The process through which the national budget is prepared, placed and passed in the Parliament could be strengthened from a climate perspective given the scale of expenditure and budgets in the activity.

All line ministries/divisions of GoB have already been brought under the coverage of MTBF, which is a multi-year approach to budgeting so as to link spending plans of the government to its policy objectives. The MTBF seems to be a step forward in the sense that it allows the line ministries to plan ahead. However, it has quite a long way to go, at least in regard to climate change aspects. Ministry spend is driven by sector policy rather than climate strategy and there was evidence that substantial adaptation expenditure, particularly of capital works in Local Government, did not appear to reference Climate Change as a policy driver in the Ministry Budget Framework. The integrated Budgeting and Accounting System (iBAS) has the flexibility to add new functionalities to capture monitoring and evaluation information.

19.2.3 Policy Review

The study reviewed national and international policy and strategy in respect of climate change, but also reviewed sector policy in key areas of government activity that influence the government's response to climate change. The policy review used a framework that recognised supportive, non-supportive and neutral policy on a sectoral basis and also a review of direct climate change policy.

Climate change policy operates in a competitive policy environment in Bangladesh. The government's priorities at this time include energy and transport which are key drivers of economic growth (Finance Division 2009, 2011; The Daily Star 2011). A brief review of energy and power policy revealed a dilemma for the country in that the reliance on dwindling stocks of natural gas, which is used for about 80–90 % of electricity generation is planned to be replaced by a significant increase in the use of coal as well as renewables. It is understood that National Coal Policy is currently being developed. With its historical experience of vulnerability to weather disasters, Bangladesh has taken several steps in recent years to embed climate change in national policy making. However whilst climate change policy is a new element in national policy and development partner support, it is being framed within the broader policy contexts relating to development and response to disasters. This means that sectoral policy rather than climate change strategy is most prominent in driving government spend in some key spending ministries. It remains a concern that climate related strategy is not effectively transacted to policy and therefore to implementation and the attendant co-ordination architecture of accountability, performance and governance that is provided by the MTBF and the ADP.

As regards the policy and strategy making process in Bangladesh, experience so far suggests that most polices are driven by experts and bureaucrats, following a top-down process and although the participation of stakeholders has significantly increased, the quality of participation of poor people appears to have remained unsatisfactory. There is no exclusive national policy that deals with climate change in Bangladesh. The BCCSAP strategy does not specify which one, out of the 28 adaptation modalities, should be prioritised over the others and in which order the country implements such a long list of adaptation programmes. The absence of both prioritisation and costing should be addressed.

The development of climate change policy in Bangladesh has been stimulated and promoted by the international context. Reciprocally, Bangladesh has helped develop Least Developed Country (LDC) positions and particularly contributed to debates on climate finance. Bangladesh's vulnerability in a global context has given it moral voice within the international arena and it has championed the LDCs. In the longer term, the country's economic development may lead it into the middle income group- indeed that is a goal of political interests. This would mean it would benefit less from international climate funds (COWI and IIED 2009; UNAGF 2010).

The Government of Bangladesh led the development of the innovative Bangladesh Climate Change Strategy and Action Plan (which included low carbon dimensions), and was an early first from an international perspective. The strategy is beginning to be the critical reference document in cross planning processes in Government and for funding mechanisms such as the BCCTF and the BCCRF. However, the document is now almost 3 years old and could perhaps be usefully revised and relaunched to ensure that high awareness levels at Ministry level are maintained and enhanced where necessary. Coupled with renewed efforts for coherent development planning, in which climate change can be embedded, the country is moving ahead on climate change.

Analysis of policy and programmes in many Ministries shows how wide and strong the connections are to climate change. Climate change impinges on the responsibilities of a wide range of Ministries although the Ministry of Environment and Forests has the technical lead. Accordingly, in recent years a large number of investments have been made by a range of Ministries, for example in coastal infrastructure and crop development which provide a base from which to improve climate resilience. The active disaster risk management agenda has been a long running focus for development, and helped put in place some local planning processes and policy transformations which help provide resilience for climate change.

19.2.4 Institutions Review

The institutions reviewed in this study included an international and national institutions involved in climate change in Bangladesh. This was a wide and complex constituency of interests that included central Ministries, line Ministries, local government, NGOs, the private sector and development partners.

The constituency involved in climate issues in Bangladesh is wide and diverse. The study identified 37 Ministries (plus their departments and autonomous bodies) as well as more than ten Donors on a multi lateral and bi-lateral basis, Local government, NGOs, households and private sector are also active in climate sensitive activity. This presents challenges and hazards to coherence and co-ordination.

Spurred on by direct experience of some extreme weather catastrophes, there has been increased focus on handling climate induced vulnerabilities in the light of climate change across the national political consensus. Some of the dynamism and energy has resulted in tangible outcomes with new national and sectoral policies and institutions being developed in recent years all of which included climate change concerns (OECD 2003).

Ministries such as Local Government, Agriculture, Social Welfare, Water Resources, Food and Disaster Management have climate change components and mandates. These Ministries receive funds to implement programs through the Annual Development Plan (ADP) and non-development budgets. The Ministry of Environment and Forests (MoEF) has the mandate to implement projects from the BCCTF and BCCRF. Therefore, there remains a tension among the Ministries over climate change related issues owing to the tension that exists between the development of policy and the differences in budget between institutions. This situation makes the case for clarification and specialisation of institutional mandates and for strengthening allocative processes within the MTBF and ADP (Haque 2009; Hedger 2011).

The lack of intra-government coordination mechanisms is a limitation. The bureaucracy appears to have hindered progress in this regard which points towards a real imperative in developing these co-ordination mechanisms. The study identified three aspects of co-ordination within Government which are worth to illustrate a bit.

Policy Co-ordination is a key area of expected sets of coordination. We understand this policy coordination as the achievement of balanced influence between sector policy and climate change policy given the evident level of integration of climate change and climate in the delivery of services. Both sectoral policy and the national climate change strategy have influence and thus must be adequately balanced. This is the role of Planning Commission.

Technical Co-ordination is also an important aspect of desired coordination and this role lies with MoEF at the moment and has evolved from an environmental mandate. However, large elements of the climate response in Bangladesh at this stage relate to adaptation strategies led by other Ministries ranging from infrastructure to social protection programmes as well as a strong link to disaster risk reduction (DRR) (DMB 2010; DMRD 2008, 2010; Zakir 2011).

Financial and Performance Co-ordination is critical to get success in whole of effectiveness in climate finance in Bangladesh. This role lies with Finance Division and is implemented via the MTBF which acts as a governance and performance management mechanism as well as matching resources to policy. Also, if the proliferation of funding sources is taken into account—at least five were identified—Finance Division has a crucial role in the co-ordination of funding.

The interface between each coordination function takes on crucial and central importance. This is an obvious and desirable need to improve the flow of funds and to ensure that climate change is reflected properly in implementation. There are mutual interfaces between all three coordination functions, between Finance Division and Planning Commission in the funding of the ADP, between Planning Commission and MoEF in the development of policy and between Finance Division and MoEF through implementation of the MTBF. Currently, the main responsibility to foster adaptation lies with the lead institution, Ministry of Environment and Forest (MoEF). Unfortunately, its performance so far appears to have been limited for many reasons, such as weak structure, duality in mandate, lack of manpower and trained human resources and weak legal framework. It is argued that the MoEF has neither a clear legal mandate as yet, nor specific Rules of Business to lead all the activities centred on climate change in the country (GED 2010).

It is encouraging to note that the NGOs of Bangladesh have been playing an important role in reducing climate change induced hazards. Some of the NGOs are engaged in massive public awareness campaign including preparedness training on climate change and sea-level rise and their impacts. Nevertheless, their efforts are not properly reflected in national programmes. A substantial portion of donors' assistance is channelled through NGOs. However, "they operate completely outside the Joint Country Strategy (JCS) framework, leaving scope for potential overlap and duplication with the development programmes of the government". There is also insufficient capacity of local bodies to plan and manage climate related projects continues to remain a major challenge to improve on climate vulnerability. In addition to intra-government co-ordination, the co-ordination between institutions i.e. national, regional and local governments would appear to be quite limited, undermining the effectiveness of the results that the project outcomes are designed to achieve. This is perhaps most sharply illustrated by the absence of climate change references in the MBF of Local Government.

The involvement of the private sector is at its initial stage, and offers a lot of potential opportunities. Bangladesh has not yet formulated a policy in relation to private sector involvement in climate change and has not set any target of preferred mix of public and private funding or delivery modalities. This must be considered more fully in the development of a National Climate Fiscal Framework Development partners and Government have separated climate funding from mainstream Government planning and expenditure for their separate reasons. On the Government side the grounds are that current processes of assessment within the Planning Commission are slow and would delay spending. The functioning of Local Consultative Group on Environment and Climate Change is yet to gain momentum.

19.2.5 Local Government Review

The adaptation component of the climate change agenda is a familiar one for many in Bangladesh. While, local stakeholders are not always able to distinguish between development expenditure and climate related expenditure, experiences of flooding, cyclones and other climate related impacts have raised significant awareness of the challenges that Bangladesh faces. In general, local stakeholders identified climate impacts as cyclones, deforestation, tidal surge, salinity, water logging, flooding and drought. The effects on people's daily lives include loss of livelihoods, ground water depletion, irrigation problems, health problems and limited access to schools and health facilities. However, less is known by these local stakeholders about the causes of climate change and the need for mitigation.

The two most popular strategies for addressing climate change identified by local stakeholders is infrastructure development and sustainable and alternative livelihoods, and that capacity building is necessary to enable people to work and development solutions to address climate impacts. However, this does not support the findings that a large proportion of central government funds, and some donor funds, are already allocated to Union Parishads (UPs) to implement infrastructure development (LGD 1998, 2009a, b).

There are several sources of climate related finance found at the local level: central government funds, donor funds, private sector donations, household spending and local government internally generated revenue. On average, 14 % of the UPs and Pourashavas' budgets are sensitive to climate change. Of this, the budgets of UPs and Pourashavas in coastal regions spend more than those from the floodplains and Barind. Of the schemes that UPs and Pourashavas deliver, safety net schemes, such as 100 day employment scheme, have a high sensitivity to climate change, of around 48–50 %. While both ADP and Local Government Support Project (LSGP)/ Local Government Support Project Learning and Innovation Component (LGSP LIC) have similar sensitivity to climate change, between 11 % and 13 %, LGSP/ LGSP LIC is made up of a larger amount of money and therefore able to make a larger contribution to addressing climate change (Deopara Union Parishad 2011; Gabura Union Parishad 2011; Garoukhali Union Parishad 2011; Kunder Char Union Parishad 2011; Lata Union Parishad 2011; Padmapukur Union Parishad 2011; Paler Char Union Parishad 2011; Rishikul Union Parishad 2011).

In addition to these funds, household and individual's spend their own financial resources on addressing climate change impacts. Most damages exceed poor households' income, although some financial and non-financial support is provided from either government, donors or NGOs, such as rice and accommodation. While the richer and middle income groups have more resources to reduce damages from climate impacts, ill-preparedness to the increased frequency of extreme weather events and limited government, donor and NGO support could push them into poverty over time.

Central government funds are usually allocated to Zilas and Upazilas for further allocation to UPs. Some donor funds use the national system to channel funds to UPs, such as LGSP/LGSP LIC, but most channel funds directly to NGOs that bypasses the government system. The effectiveness of donor funds are yet to be assessed but their accountability frameworks are wide-ranging and complex. One aspect that is consistent in many of the funding mechanisms is the limited involvement of, or autonomy for, UPs in the planning and budgeting of these funds. UPs have limited power, financial autonomy and capacity to address climate change. Local planning and budgeting is a linear operational process whereby UPs implement the directives of central government and follow guidelines set by Upazila administrative offices (The Daily Star 2010). Moreover, there is a disconnect between national and local government bodies, and a strained relationship between local administrative offices and local elected bodies. Questions are raised as to whether UPs are equipped and well positioned to implement large scale climate related projects that requires the management of large volumes of funding and coordination with a range of national and local bodies.

Finally, NGOs play a significant role in Bangladesh, including the delivery of climate related finance. They play an important and added value role in the area of mobilizing and engaging communities, providing technical expertise and ensuring transparency of expenditure. However, the lack of coordination with local government bodies and competition between NGOs present a challenge in tracking climate expenditure and aligning efforts to addressing climate change in a more integrated manner.

19.3 Looking Ahead: Way Forward

There are established planning and allocation mechanisms within Government that, with strengthening, can bring improved co-ordination, allocative efficiency and consequently better outcomes to climate issues in Bangladesh. The creation of alternative mechanisms will add further complexity to a substantial undertaking in Bangladesh that already utilises considerable domestic resources. Climate issues in Bangladesh are a matter of national interest from both a physical implementation and financial and economic perspectives. In summary therefore, it is recommended that the next stage in the process for Bangladesh should focus on three main initiatives in respect of Climate funding.

The government should be supported to ensure balance the policy influences at play in climate and the wider policy arena by strengthening of existing country architecture, strengthen and utilise existing, established Government planning and financial allocation mechanisms of the MTBF and the ADP to manage climate funds and to manage results through a strengthened performance management arrangements within the MTBF and at the institutional level. Accordingly, a total of 20 recommendations are set out below for consideration. An indicative sequence is shown in diagrammatic format at Fig. 19.1: Indicative Sequencing of Next Stage Recommendations.

19.3.1 Climate Strategy

In relation to have a right climate strategy, some consideration should be given to a further review of the BCCSAP in the near future to ensure that it remains fully relevant to current circumstances. Further consideration should be given to including more detailed costing of the needs of Bangladesh in respect of climate and climate change to provide a cornerstone for the development of a Climate Fiscal Framework. This revision should take into account the potential role, risks and responsibilities of the private sector (including households) in respect of climate change with the intention of engaging the interest, resources, skills and knowledge available in that sector of the economy.

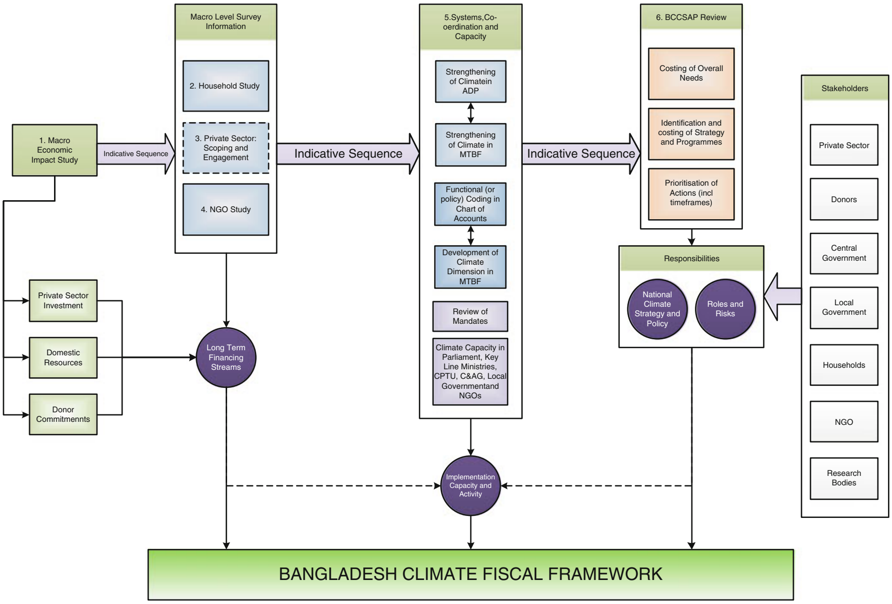


Fig. 19.1 Indicative sequencing of next stage recommendations

19.3.2 Public Finance Management

In public financial management, the development of a national climate fiscal framework is a high priority to ensure allocative efficiency and effective transaction of strategy to both policy and budgets. The framework should recognise some of the critical factors: the risks, roles and responsibilities that should be allocated to each institutional sector within Bangladesh including central government, local government, donors, NGOs, households and the private sector; the allocation of funding responsibilities to all aspects of climate finance and activity; the need for a focal point financial framework that ensures the long term sustainability of funding streams; ensuring that long terms plans in a revised and costed BCCSAP can be funded or prioritised for funding on a rational basis within a climate fiscal framework; the capacity on human resources (HR) and institutional basis to implement the framework on a sustainable and achievable basis.

The current level of expenditure on climate sensitive activity, around US$1 billion per year, is significant in economic terms. It was noted in BCCSAP that a study of the long term macroeconomics of climate [Thematic area 4; Programme 5 (T4P5)] was recommended, but this has not yet been conducted. This study should be conducted as soon as possible to support the development of a climate fiscal framework and should address, inter alia, considering an evaluation of the economic impacts of not spending at the current levels, an evaluation of the economic development effects of the current expenditure, including the effects at household level, an evaluation of the potential long term funding streams for financing climate change activity, including the feasibility of hypothecated taxation and potential of donor sources, an evaluation of the sustainability of the current and required long term spend on climate change and climate sensitive activity, the relationship between the government's energy and transport policies and climate policy in the longer term with a view to achieving a balanced accommodation of each priority.

It is recognised that the GFSM 2001 does not include a functional classification for climate change. However, it would be a useful development for the Government if some functional (or policy) recognition of climate change, perhaps on a thematic basis according to BCCSAP themes, could be incorporated into the structure of the Chart of Accounts presently under revision.

There are presently five mechanisms delivering climate finance in Bangladesh and as each addresses all six themes in BCCSAP some consideration should be given to a review of the co-ordination of this funding activity. There is a case for explicit recognition of the appropriateness of the use of each funding mechanism for particular thematic purposes, as would appear to be the case with the ADP contributing high volumes of the planned expenditure on infrastructure. The mandates and intended roles of each funding source should therefore be established with a view to eliminating the risk of gaps and overlaps. This may also have the benefit of further developing specialist skills and knowledge in particular aspects of climate spend and activity.

It was noted that each finance delivery mechanism within the government system operates to different levels of efficiency in respect of delivering spend. Typically, for example, the ADP tends to underspend by a greater amount than the non-development budget. It is therefore recommended that some consideration is given to funding capacity building public financial management initiatives with the objective of ensuring equality of process-efficiency across the climate finance delivery mechanisms.

Guidelines for the award of funding of climate change related projects proposed by both government and non-government entities to the BCCTF should be developed immediately to maximize the utilization of limited resources allocated to BCCTF. The development of procedures for the BCCTF should also include a clear statement of the role of the Controller and Auditor General in respect of the fund. The activity of the BCCTF should also be reflected in the MTBF and MBF of the Ministries with a view to accommodating the need for performance and accountability in respect of fund expenditure.

In respect of the BCCRF and BCCTF some consideration should be given to integrating the funds with existing key country systems, whilst retaining their intended flexibility and agility of response. As a parallel initiative strengthening of these key country systems (MTBF and ADP in particular) would seem to be an effective long term strategy with wider benefits than the impacts on climate change response alone. In particular, the BCCRF should give serious consideration to funding institutional strengthening activities, including the reduction of fiduciary risk, as a key strategy in improving co-ordination of climate sensitive activity.

Some capacity building activity should be considered for the Controller and Auditor General's Office to enable him to address climate funding issues in the forthcoming audit plan and in particular to review climate finance in the forthcoming planned and regularity performance audits. A review of procurement regulations to incorporate climate sensitivity should be considered for the Central Procurement Technical Unit (CPTU).

19.3.3 Climate Policy and Planning

In relation to Climate Policy and Planning, Ministry Budget Frameworks presently do not always identify climate and change activity. Some consideration should be given by the Finance Division to the inclusion of a climate change dimension or "marker" to the MTBF procedures to ensure that the activity is fully recognised by line Ministry accountability, performance management and governance structures. Such an initiative was successfully implemented by the Finance Division in respect of gender and poverty in recent years.

Consideration should be given to strengthening key relationships and co-ordination processes in the development and implementation of climate policy. In particular, three aspects should be focussed upon the transaction of strategy to implementation via sector policy should be addressed by ensuring that the climate dimension is adequately addressed at sectoral level. This must involve setting a climate dimension or marker within the MTBF process to identify budgets, promote accountability and, generally, match expenditure and performance plans with climate policy. It should also involve standards and guidelines, established by the Planning Commission, to ensure that the climate dimension is considered in all policy development. Some consideration should be given also to creating a climate marker within the ADP.

The relationship between, and respective capacities of, the Planning Commission and Finance Division in interpreting and funding climate policy should be strengthened to ensure appropriate allocative efficiency of resources and consistency with policy and priority intentions. The communication of climate change strategy to line Ministry level and on to department, autonomous body and local government level should be a priority to ensure adequate reflection within Ministry budget frameworks.

19.3.4 Climate Institutions

The institutional mandates in respect of the three aspects of co-ordination identified in the study (technical, policy and financial/performance) should be clarified and steps taken to strengthen these and the interfaces between them. This should involve specific cross-institution actions involving Planning Commission, Finance Division, MoEF, DRR, Local Government Division and other institutions within government that make a significant contribution to climate sensitive activity.

There is also a case for strengthening the co-ordination and transaction of climate policy, finance and delivery between the levels of government and the various non-government institutions, including the private sector, involved in climate change in Bangladesh. It is also important that the private sector and civil society organizations create more inclusive partnerships so that all their efforts are coherent and have greater impact on reducing climate vulnerability. Existing institutions that could potentially be developed in this regard could include the Ministry of Industry and the NGO Bureau.

The National Parliamentary Standing Committee on Environment should be empowered so that the body, with its legal authority, can oversee and guide various activities related to climate change, including involvement in international negotiations for adaptation. They may be actively involved in mainstreaming adaptation while sectoral allocations and priorities are made for the annual development plan. There is a case for a programme to be delivered in this area as a means of engaging the Committee and developing political leadership on climate issues. This initiative should also consider the formation of a function, perhaps a standing committee, to scrutinize projects/expenditure proposals regarding climate change related activities before placement of the overall budget. This would perhaps be a valuable programme for funding by the BCCRF as support for political level engagement and leadership.

As regards knowledge management, academic and research bodies and universities should give more efforts toward facilitating generation of information and knowledge related to climate change and its impact as it is widely acknowledged that long term studies on the effects of climate change are necessary. This was a particular limitation of the CPEIR in that only three historic years were considered to give an initial snapshot and trend in respect of funding and spend.

The BMCs and Climate Change Cells of line ministries should be equipped by personnel with expertise in the area of climate activities. Such a development could be considered for funding under the capacity building theme of BCCSAP. On the basis of strengthening institutional memory and business continuity, some consideration should be given to establishing a critical mass or group of climate specialists within government who have a portable set of skills that may be relevant to a number of Ministries involved in climate response. This recommendation is distinct from the administratively based creation of climate change cells or a climate change unit in the MoEF and focuses more directly on the HR requirements to equip both Climate Cells and BMCs with the necessary skills to establish performance evaluation and monitoring skills relevant to the cross cutting and pervasive nature of climate response in the Government of Bangladesh. It is clear that to be workable, such an initiative would require a good level of engagement with the Public Service Commission/ Ministry of Establishment to ascertain both its feasibility and scope. It is also clear that such a group would require a diverse range of policy and operational skills given the diversity of professional disciplines involved in the climate response.

As a step towards bridging relationships between different local stakeholders by highlighting each of their strengths and weaknesses in delivering climate finance, the conduct of an appraisal of the capacity and comparative advantages of different local stakeholders to manage larger scale projects should be undertaken. For example, while UPs should be involved in climate related project, they may not be equipped with the capacity and resources to take on certain roles such as overall supervision and monitoring and evaluation of large scale projects. It may be that local administrative offices and NGOs should utilize their expertise in financial management, technical support, supervision and monitoring of climate finance, and local elected bodies should be equipped with necessary power and capacity to plan, budget and manage programs using a participatory approach.

Building on the existing vulnerability mapping database used for safety net programs, there is an urgent need to conduct further empirical and robust assessments of household spending on climate change related activities. This information could help target and prioritize funding to address the needs of households that are spending a large proportion of their income on addressing climate impacts. While there is a need to safeguard those most vulnerable, there is also a need advocate preventative measures to those with high- or middle- levels of income from slipping into poverty as a result of climate impacts.

19.3.5 Non Government Organisations and the Private Sector

Given the time constraints and scale of activity in climate issues in Bangladesh, it is felt that insufficient analysis was conducted in respect of both NGOs and the private sector. It is therefore recommended that a review or survey study is conducted in respect of climate sensitive activity in these economic sectors. The study should focus on the sources and application of finance and the policy and strategy architecture that frames spend.

References

Alam K, Shamsuddoha M, Tanner T, Sultana M, Huq MJ, Kabir SS (2011) Planning exceptionalism? Political economy of climate resilient development in Bangladesh. In: Understanding the political economy of low carbon and climate resilient development. Institute of Development Studies

Asian Tiger Capital Partners (2010) A strategy to engage the private sector in climate change adaptation in Bangladesh. Prepared for the International Finance Corporation

Ayres J, Alam M, Huq S (2009) Adaptation in Bangladesh. In: Tiempo: a bulletin on climate and adaptation, p 72

BSS (2011) BCCTF approves six projects. Bangladesh Sangbad Sangstha (BSS). http://news1.bssnews.net/newsDetails.php?cat=107&id=209756&date=2011-11-23. Dated 23 Nov 2011

BSS (2012) Trustee Board on climate change okays 5 projects worth Taka 97 crore. Bangladesh Sangbad Sangstha (BSS). http://news1.bssnews.net/newsDetails.php?cat=107&id=209756&date=2011-11-23. Dated 25 Jan 2012

Burton I (2004) Climate change and the adaptation deficit. Occasional Paper – 1, Adaptation and Impacts Research Group (AIRG), Meteorological Service of Canada, Environment Canada, Downsview

CCC (2007) Bangladesh must participate meaningfully and effectively in international processes to work out a viable and equitable future climate regime. Climate Change Cell (CCC), Department of Environment, Ministry of Environment and Forest, Government of Bangladesh

COWI and IIED (2009) Evaluation of the operation of the Least Developed Countries Fund for adaptation to climate change. GEF Evaluation Office and Ministry of Foreign Affairs, Evaluation Department Government of Denmark. http://www.evaluation.dk

CPD (2008) Accra Conference on aid effectiveness: perspectives from Bangladesh. CPD Occasional paper Series, paper 76, Centre for Policy Dialogue (CPD), Dhaka. url:http://www.eaber.org/sites/default/files/documents/CPD_Rahman_2008_02.pdf

Deopara Union Parishad (2011) Annual budget report. Deopara, Dhaka

DMB (2010) National Plan for Disaster Management (NPDM) 2008–2015. Disaster Management Bureau (DMB), Disaster Management and Relief Division (DMRD), Government of Bangladesh, Dhaka

DMRD (2008) Comprehensive Disaster Management Programme (Phase I). Disaster Management and Relief Division (DMRD), Ministry of Food and Disaster, Government of Bangladesh. http://www.cdmp.org.bd/

DMRD (2010) Comprehensive Disaster Management Programme (Phase II). Disaster Management and Relief Division (DMRD), Ministry of Food and Disaster, Government of Bangladesh. http://www.cdmp.org.bd/

Finance Division (2009) Towards revamping power and energy sector: a road map. Ministry of Finance Government of Bangladesh

Finance Division (2011) Power and energy sector road map: an update. Ministry of Finance (MoF). Government of Bangladesh, Dhaka. www.odi.org.uk/resources/docs/3431.pdf

Gabura Union Parishad (2011) Annual budget report. Gabura, Dhaka

Garoukhali Union Parishad (2011) Annual budget report. Garoukhali, Dhaka

GED (2010) Poverty, Environment and Climate Mainstreaming (PECM) Project. General Economics Division (GED), Planning Commission, Government of Bangladesh. http://www.pecm.org.bd

GoB (2008) Multi donor trust fund for climate change (MDTF): Draft Concept Note. Government of Bangladesh

Haque AK (2009) An assessment of climate change on the annual development plan (ADP) of Bangladesh. United International University, Dhaka

Hedger M (2011) Climate finance in Bangladesh: lessons for development cooperation and climate finance at national level. Institute for Development Studies, London

Huq S, Rabbani G (2011) Climate change and Bangladesh: policy and institutional development to reduce vulnerability. J Bangladesh Stud 13:1–10

IMF (2001) Government Finance Statistics Manual. United Nations Statistics Division, United Nations, New York. http://unstats.un.org/unsd/

IMF (2011) IMF Executive Board Concludes 2011 Article IV Consultation with Bangladesh. Public Information Notice (PIN) No. 11/132. International Monetary Fund (IMF), Washington

Kunder Char Union Parishad (2011) Annual budget report. Kunder Char, Dhaka

Lata Union Parishad (2011) Annual budget report. Lata, Dhaka

LGD (1998) Local Government (Upazila Parishad) Act. Local Government Division (LGD), Ministry of Local Government and Cooperatives, Government of Bangladesh, Dhaka

LGD (2009a) Upazila Parishad (Amendment) Act. Local Government Division (LGD), Ministry of Local Government and Cooperatives, Government of Bangladesh, Dhaka

LGD (2009b) Local Government (Union Parishad) Act. Local Government Division (LGD), Ministry of Local Government and Cooperatives, Government of Bangladesh, Dhaka

MoPEMR (2011) UNDP Global Project: Capacity Development for Policy Makers to Address Climate Change. Ministry of Power, Energy and Mineral Resource (MoPEMR), Government of Bangladesh, Dhaka

Narain U, Margulis S, Essam T (2011) Estimating costs of adaptation to climate change. Clim Pol 11(3):1001–1019

OECD (2003) Development and climate change in Bangladesh: focus on coastal flooding and the Sundarbans. S. Agrawal, T. Ota, A.U Ahmend, J. Smith and Mvan Aalst. OECD Environment

Directorate/Development Cooperation Directorate Working party on global and structural policies; Working party on development cooperation and environment

OECD (2011) Handbook on the OECD-DEC climate markers. Preliminary version. http://www.oecd.org/dac/aidstatistics/48785310.pdf

Padmapukur Union Parishad (2011) Annual budget report. Padmapukur, Dhaka

Paler Char Union Parishad (2011) Annual budget report. Paler Char, Dhaka

Polycarp C (2010) Governing climate change finance in Bangladesh. An assessment of the Governance of Climate Finance and the Paris Declaration on Aid Effectiveness. A report prepared for the capacity development for development effectiveness facility, October 2010

Rishikul Union Parishad (2011) Annual budget report. Rishikul, Dhaka

Stadelmann M, Roberts JT, Amchaelowa A (2010) Keeping a big promise: options for baselines to assess "new and additional" climate finance. CIS Working Paper nr 66 2010 University of Zurich, http://ssrn.com/abstract=1711158, 18 Nov 2010

Tanner T, Mitchell T (2008) Entrenchment or enhancement: could climate change adaptation help reduce chronic poverty? CPRC Working Paper. Chronic Poverty Research Centre, University of Manchester, Manchester

The Daily Star (2010) Upazila chairman vis a vis UNO. http://www.thedailystar.net/newDesign/news-details.php?nid=153870. Dated 7 Sep 2010

The Daily Star (2011) Power sector tops priority. Dated May 30 2011. http://www.thedailystar.net/newDesign/news-details.php?nid=187821. Accessed 22 July 2011

UNAGF (2010) Report of Secretary General's High level Advisory Group on Climate Change Financing, 5 Nov 2010

World Bank (2010a) Bangladesh and state of the economy and FY11 Outlook. World Bank, Washington

World Bank (2010b) Economics of adaptation to climate change: Bangladesh case study. World Bank, Washington

World Bank (2010c) Meeting of the PPCR sub-committee: strategic programme for Climate Resilience Bangladesh. CIF report PPCR/SC.7/5 October 25, 2010. World Bank, Washington

Zakir A (2011) Bangladesh: National Progress Report on the Implementation of the Hyogo Framework for Action. Disaster Management Bureau (DMB), Disaster Management and Relief Division, Ministry of Food and Disaster Management, Government of Bangladesh, Dhaka

Chapter 20
Planning "Exceptionalism"? Political Economy of Climate Resilient Development in Bangladesh

Khurshid Alam, Thomas Tanner, Md. Shamsuddoha, A.K.M. Mamunur Rashid, Moshahida Sultana, Muhammad Jahedul Huq, Sumaiya S. Kabir, and Sifayet Ullah

Abstract Following three major disasters in 2007, Bangladesh intensified its effort to tackle climate change through development of the Bangladesh Climate Change Strategy and Action Plan (BCCSAP). The process of plan formulation led to debates nationally and internationally regarding the financing and integration of climate change into development planning. Using a political economic lens, this article illustrates how major national initiatives around international problems must be understood in terms of the interplay of actors, their ideas and power relations. The article argues that: (a) power relations among actors significantly influenced the selection of ideas and implementation activities; (b) donor concerns around aid effectiveness and consequent creation of parallel mechanisms of planning and implementation may run counter to both the mainstreaming process and the

K. Alam
Think Ahead Limited, Dhaka, Bangladesh

T. Tanner
Institute of Development Studies (IDS), Sussex, UK

Md. Shamsuddoha
Participatory Research and Development Initiates, Dhaka, Bangladesh

A.K.M.M. Rashid (✉)
Poverty Environment and Climate Mainstreaming Project, UNDP Bangladesh, Dhaka, Bangladesh
e-mail: nemoibsru@gmail.com

Md. Sultana
Department of Accounting and Information System, Dhaka University, Dhaka, Bangladesh

M.J. Huq
Action Aid, Dhaka, Bangladesh

S.S. Kabir
British Council, Dhaka, Bangladesh

S. Ullah
UNDP Bangladesh, Dhaka, Bangladesh

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*, Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0_20, © Springer Japan 2013

alignment of assistance with country priorities and systems; (c) climate change planning processes must be opened up to include actors from across sectors, population groups and geographical areas.

Keywords Actors • Climate resilient development • Ideology • Political-economy • Power

20.1 A Brief Account of the Study

20.1.1 Introduction

This chapter is based on research into the policy processes underpinning climate resilient and low carbon development (Tanner and Allouche 2011). Taking Bangladesh Climate Change Strategy and Action Plan (BCCSAP) as a case study, the study explores the interplay between actors in the space that opened up for climate change planning in Bangladesh. This also examines relative importance of ideology and power configuration between actors in generating and deciding over the ideas for this planning. Finally this looks into how internationally defined ideas influence and gets translated in national planning. The original report of the study was published in IDS Bulletin (volume 42, Number 3; May 2011 published by Institute of Development Studies and Wiley-Blackwell).

20.1.2 Background of the Study

It was not until 2007 when Bangladesh faced two devastating disasters, consecutive monsoon floods an category four cyclone *Sidr*, climate change received significant political attention. Cyclone *Sidr* killed over 3,000 people causing an economic loss of US$1.7 billion while the floods caused damage amounting to US$1.1 billion. The occurrence of these major disasters and the subsequent debate about its link to climate change sparked an intensification of efforts to tackle long term climate change impacts in Bangladesh.

Underpinning the new approach was the recognition that climate change posed a serious threat to Bangladesh's desire to become a middle income country by 2021.[1] Central to the post 2007 efforts was the formulation by the Government of Bangladesh (GoB) of its *Climate Change Strategy and Action Plan* (BCCSAP) and a National Climate Change Trust Fund. An Act of Parliament passed in 2010 then established a donor funded Bangladesh Climate Resilient Fund (BCRF) formerly

[1]The Bangladesh Vision 2021 was accessed on 24 December 2010 from http://boi.gov.bd/about-bangladesh/government-and-policies/government-vision-2021?format=pdf.

known as the Multi Donor Trust Fund (MDTF), and the Climate Change Unit housed in the Ministry of Environment and Forests (MoEF). This report refers these planning collectively as “post *Sidr* planning”.

This planning process has received considerable national and international attention for two reasons. First, that the planning will determine the sustainability of development potential of the most climate vulnerable country. Second, that Bangladesh is linked to and plays a vital role in international climate change diplomacy and politics.

The process and content of post 2007 plans are considerably different in nature and scope from previous climate change related initiatives such as National Adaptation Plan of Action (NAPA) that was formulated under the UN Framework Convention on Climate Change (UNFCCC) in 2005. While NAPA considered only urgent and immediate priorities for adaptation, the BCCSAP is more comprehensive and focused on medium and long-term actions through pillars which mirrored the areas set out in UNFCCC negotiations under the Bali Roadmap i.e. adaptation, mitigation, technology transfer and financing. This significant shift in planning was influenced by transformations in ideas, knowledge, actors and incentives in the post NAPA years which generated a domestic political economy. These include:

(a) Increase in political commitment for climate change
(b) Rise of new ideas and knowledge on and their contestation in tackling climate change
(c) Emergence of new climate change actors joining with established environmentalists and their interplay in the decision making
(d) Influence of international climate change politics over national processes
(e) Evolving estimation of huge sum of resources required to make the country resilient
(f) Increasing perception of huge inflow of funds as an incentive for change coupled with frustration over reality of too little.

20.1.3 Analytical Framework and Methodology

Climate change has moved to the centre stage of public concern in a very short space of time (Giddens 2008), pushing development policy and practice to incorporate resilience to the impacts of climate change and a low carbon global future. There is a reasonable understanding about the objectives of climate resilient and low carbon development; the change processes required for their delivery are less well understood. The study assumes that the changes processes are triggered by international politics of climate change (Dessler and Parsons 2006), the need for new global institutions (Yamin and Depledge 2004) and the business strategy of global corporate actors (Levy and Kolk 2002). Likelihood of significant resource inflow to national level influences institutional landscape, knowledge and ideas which eventually opened up space for debate and interplay of actors in shaping kind of policy and practices required for a climate resilient development. The study further assumed that due to transnational nature of the problem global politics of climate change would significantly influences the national policy and practices.

Public Policy making and national planning have distinct meaning in academic tradition especially in public policy studies. This study, however, adopted the planning process similar to public policy making, which can broadly be defined as: (a) setting the agenda; (b) specification of alternatives from which a choice is to be made; (c) an authoritative choice among these specific alternatives; and (d) implementation of decision (Kingdon 2003). Both planning and policy making follow a similar path i.e. conceptualisation, negotiation and implementation, that Kingdon in his book *Agenda, Alternatives and Public Policy* further describes how separate steams of problem, solutions and politics converge to move an issue into the public policy agenda towards potential government action. While Kingdon's theoretical model provides useful analogy for analysing public policy or planning into a political context, studies (Sifayet 2008) which identify their shortcoming, examine policies in non-western countries where international actors and policies play a significant role in domestic policy making.

This chapter bases its analytical framework on the new political economy approach developed by the Institute of Development Studies, UK (IDS) to understand climate change policy processes at national level (Tanner and Allouche 2011). This approach examines the complexity of decision making and policy processes around tackling global climate change issues at national and sub-national level. It breaks the policy process into three analytical areas of *conceptualisation*, *negotiation* and *implementation* of climate change initiatives, the framework analyses the interplay between the three lenses of ideas, power and resources. The analytical hypothesis suggests that each of these concepts tends to be predominant at one stage of the policy process of the political economy of climate change. Ideas and ideologies are predominant in the conceptualisation phase, power in the negotiation phase and resources, institutional capacity and governance in the implementation phase.

Crucially, the new political economy approach goes beyond orthodox international political economy analyses, which are often focused on material factors and ignore how ideas and ideologies also determine policy outcomes (Barnett and Finnemore 2004). These ideological framings often become part of narratives that are supported by particular actors, networks and institutions and justify a particular set of actions.

The study used following key definitions:

- **Actors:** An actor refers to a person, group, organization, or system who played a role, influence and being influenced (by the plans) in the climate change planning.
- **Ideology:** The study adopted a neutral conception of ideology as described in the International Encyclopaedia of Social and Behavioural Science that refers to it as "a discrete belief system which animates social and political action". The study finds five dominant ideologies which are described later.
- **Power and power configuration:** In terms of power configurations between actors, the study sought to understand the formal and informal power relations and structures. The analysis of actors, interest groups and structures will ideally show where real power in a society lies, how power is distributed and possible

conflicts of interests. It may also point to what kind of power is being exercised and how it is understood and perceived.

The study was conducted in September to December October 2010. It is based on 60 detailed interviews with the key actors concerned in the Bangladesh climate change planning process. At least one quarter of these actors were involved in the BCCSAP formulation, including key government officials, experts, and staff of donor agencies. The research team interviewed other key players including campaigners, academics, politicians, civil society members and researchers engaged in the debate and discussions that shaped the wider context. The research team provided all interviewees the guarantee of anonymity. These interviews were combined with a review of formal and informal documents, including government notifications, meeting minutes, formal publications, newspaper clippings and press releases.

20.2 Context of the Post Sidr Climate Change Planning

This part of the report illustrates the immediate and historic factors—domestic and international—that shaped the planning context for post *Sidr* climate change plans in Bangladesh. Chapters 2 and 3 of this book illustrate country's risk and vulnerability to climate change.

20.2.1 Key Historical Milestone of Climate Change in Bangladesh

There is no exclusive national policy that deals with the climate change in Bangladesh. A few policies developed in recent years i.e. agriculture policy 2009, national agriculture policy 1999, new agriculture extension policy 1996, coastal zone policy 2005, land use policy 2001, forest policy 1995, national water policy 1999, renewable energy policy 2008, national health policy 2010 and draft industrial policy 2010 already included climate change concerns.

Prior to BCCSAP formulation, GoB formulated a number of national and sectoral strategies and action plans: (a). national water management plan, (b) national biodiversity strategy and action plan for Bangladesh; and (c) national environmental management plan including climate viabilities.

Bangladesh produced NAPA in 2005 as a requirement of UNFCCC. The document set out 15 urgent and immediate priorities only for climate change adaptation. The document was produced through a project led by a steering committee, headed by MoEF and members of other key ministries. The process involved selected vulnerable communities while conducted consultation in the capital and other divisional cities. However, the document has been seen as external requirement thus did not receive sufficient political attention and include into national planning process.

In 2005 and 2006 Bangladesh selected as a leader of LDCs. From COP1 to COP12, Bangladesh had a strong present in international climate change negotiation.

20.2.2 Changing Institutional Landscape in Climate Change

Over the last 10 years, there has been significant change in the institutional landscape in Bangladesh is centred on and around climate change. Newer institutions within government, political system[2] and non-government research, academic, NGOs, network and campaign have been established. GoB established CCC in 2004 with the financial help of DFID and housed in DoE under MOEF. Besides, individuals such as independent researchers and experts; and institutions traditional development NGOs and research organizations,[3] adopted climate change as an issue to work with. After the national election of 2008, All Party Parliamentary Group on climate change and parliamentary committee of costal MPs were also formed.

Policies of the major bilateral and multilateral donors went through a shift to include climate change concern into their development assistance. Climate change moved from a peripheral issue to a central issue to the discussion and action of donor agencies although the change process was not generated from the country but by the changes in international policy of the donors.

- Invested in studies to understand climate change implication (for internal purpose) as well as influence broader policy initiatives.
- Some donors such as DFID and Danida commissioned screening of their programme portfolio.
- The World Bank and Asian Development Bank included climate change in their lending portfolio and country assistance strategy.

20.2.3 Shifting Climate Change Discourse

Over the last 10 years, international climate change discourse in Bangladesh has been largely translated, advanced and shaped through a number of shifts. First, this started with a sceptical view of it as "another international agenda" to a broad based development concern with high political attention in recent years. Second, although the issue has been raised and nurtured by the environmental circle the discourse continues to be shifted as a development issue and should be dealt with through regular development planning process in which both climatic and non-climatic issues should be addressed.

---

[2] All party parliamentary committee on climate change, Parliamentary committee of coastal MPs.
[3] Many of the researchers in Bangladesh conducted studies, ether to supply evidence of climate change, for international or supporting various campaigns or attract funds.

Third shift can be characterized as a justice discourse based on the principle of compensation, right to access funding, equity and the national control over adaptation resources. This discourse is largely shaped by the campaign groups, media, NGO and the current ruling government. Two important discourses shaped this agenda: (a) national government should decide how they are going to plan and spend adaptation resources; (b) people's vulnerability to climate change is constructed by socioeconomic inequity which should be addressed as part of the adaptation process. But the policy agenda of the campaigning groups covered wider context of equity which called on the Northern countries to compensate the loss caused by the climate crisis.

Climate change is beginning to play "an important role" in domestic politics which arguably started in 2009 with a press conference by the main opposition party, Bangladesh Nationalist Party (BNP), stating that Bangladesh failed to reflect its national interest as a least developed country (LDC) in COP15. There have been several responses from the ruling party, Awami League (AL), including the Prime Minister herself who mentioned climate change negotiation in COP15 as major achievement in a speech. This policy shift was underpinned by concern around the impact of climate change on development cooperation objectives such as the Millennium Development Goals and led to donor efforts in Bangladesh and elsewhere to assess and integrate adaptation concerns into agency portfolios (Tanner et al. 2007).

20.2.4 Administrative Structure Related to Climate Change

20.2.4.1 Ministry of Environment and Forests (MoEF)

This is the focal ministry for maintaining direct coordination with the UNFCCC and its related activities at global and national levels. The MoEF has several agencies and institutional mechanisms to implement its mandate of environmental and natural resource management including climate change that include:

(a) Climate Change Unit (CCU)
(b) Department of Forest (FD)
(c) Department of Environment (DoE) which houses the Climate Change Cell
(d) Bangladesh Forestry Research Institute (BFRI)

Department of Environment that was created in 1989 under the Ministry of Environment and Forest is mandated to implement the policies to ensure sustainable development, conserve and manage the environment of Bangladesh. Therefore, to focus solely on the issues of climate change the Climate Change Cell (CCC) was established in 2004 under a DFID and UNDP-funded project and housed in the DoE. CCC is tasked with integrating climate change considerations into various aspects of national planning. They lobby the Planning Commission to include climate change directives in the national development plan to be implemented by professionals and funded by the line ministries.

In January 2010, the MoEF established a "Climate Change Unit" under its own setup to facilitate the financial and institutional mechanism for implementation of the Bangladesh Climate Change Trust Fund, what the Government endowed to the Ministry through creating a Trustee for the implementation of BCCSAP 2009.

20.2.4.2 Economic Relations Division (ERD)

ERD under the Ministry of Finance is one of the important Divisions of the GoB which mobilizes external resources for socio-economic development of the country. ERD leads as the focal point of the Government for interfacing with the development partners as well as for co-ordination of all external assistance inflows into the country. It assesses the needs of external assistance, devises strategy for negotiations and mobilizes foreign assistance, formalizes and enables aid mobilization through signing of loans and grant agreements, determines and executes external economic policy. (*Source*: http://www.erd.gov.bd/index.php.)

Normally, requests for financing projects are made by implementing agencies to the donor agencies through ERD. Sometimes donor agencies which are willing to assist a project approach ERD. The ERD headed by a secretary is responsible for aid negotiation and programming. It was separated from the Planning Commission in 1978 and given the status of a Division of the Ministry of Finance with powers to decide development priorities and negotiate foreign aid programmes with donor countries. In August 1990, the Bangladesh government made an important change in the approval procedures of different projects to make them consistent with the principles of sound project management. Previously, the Planning Commission was primarily responsible for scrutiny and approval of development projects. Under the current arrangement, administrative ministries and executing agencies are responsible for examining a project before it is finally approved by the Executive Committee of the National Economic Council (ECNEC). After the approval of the projects, the relevant department or agency appoints a project director with the prior consent of the administrative ministry.

20.2.4.3 Planning Commission

The commission is the central planning body of Bangladesh. It is a body of professionals and sector specialists engaged in the formulation of macro as well as micro economic plans and policies of the government.

Through the formulation of the 5-year Plans and the Annual Development Plans, the Planning Commission in effect translates the ideas, aspirations and the commitment of the party in power. The Planning Commission is entrusted with functions of preparing national plans and programmes according to the directives of the National Economic Council (NEC).

The Commission, through multi-sectoral input–output models, makes macro economic projections and sets output targets for the sectoral activity at different time frames such as long term perspective plans like Five Year Plans and Two Year

Plans etc. Although responsibilities from planning to execution are shared between the administrative ministries and planning commission the planning process starts with the mapping of economic trends and identification of alternative possibilities by the Commission, leading to formulation of the technical framework of a plan. Ministries and agencies participate indirectly in these technical works as source of information. Planning Commission launches detailed economic, financial and technical appraisal of projects and mobilizes resources for their implementation in consultation with the Finance Division and the ERD.

20.2.5 General Policy and Strategy Making Process in Bangladesh

As per the clause of the Rules of Business 1996 clause 4(ii) "no important policy decision shall be taken except with the approval of the cabinet". Cabinet is the ultimate authority of approving a policy. There are inadequate debate on policy and legislation in Parliament. Many important matters including the Five-Year Plan are not discussed in the Parliament at all (Aminuzzaman 2002). Most policy is formulated in the ministry level are not even announced in the parliament, so it is not surprising that such policies have little public understanding and are often implemented half-heartedly (Aminuzzaman 2002).

For example, the policy on Chittagong Hill Tracts Accord was made by a handful of senior Awami League and tribal leaders with little or no actual consultation with the party, or in the parliament, or the public in general that denotes the elite domination in the process.

Flood Action Plan is an example of how supposed beneficiaries of flood control in Bangladesh—the country's poor majority—have been virtually excluded from the decision-making process. The World Bank concedes that past embankment projects have been undermined by deliberate cutting of embankments by disgruntled farmers and fishermen, and hence calls for "closer involvement of the beneficiaries" and "more cooperation among farmers". It provides no inkling, however, of how these are to be achieved in a context of military based rule and a highly inequitable land ownership pattern.

Health policy, for example, is shaped not only by certain acts but also by a stream of administrative rules and decisions interpreting, elaborating, and applying the act to particular situations (Aminuzzaman 2002). A study on health policy formulation shows that donors and bureaucrats are the dominant forces in health policy making; this causes lack of representation of people for whom the policy is nominally made.

Over the last four decades, Bangladesh has created a space for pluralistic institutions to function and take active role in influencing the policies in Bangladesh. Besides having government, political organizations, business community, and donors to take part in the policy making process, another type of institution—NGOs—evolved and established themselves as a prominent actor influencing the policy implementation. Bangladesh's slow transition from using interventionist approach towards adopting neoliberal approach has created scopes for civil society to form NGOs and actively participate in the development process. In this whole process a network of elite having access to all different kinds of institutions have gradually constellated and made these institutions to function based on trust and mutual dependency.

In summary, the two decades of policy making suggests the following trends:

- Most polices are driven by expert and bureaucrats following a top-down process. While participation of stakeholders increased, quality of participation of poor people remained weak.
- Often policy agendas are set through external requirement as oppose to domestic demand that created limited ownership by the society at large. Externally driven process created limited political ownership and often created parallel process to already existing planning process.
- Participation of political parties and debate in the parliament on major policy issues remained weak.

20.2.6 International Drivers in the Planning

The international climate change governance in 2007 and 2008 had an influence over post-*Sidr* planning in Bangladesh (Table 20.1). COP13 in 2007 created a sharp divide between developed and developing countries about the financing mechanism; whether it should be bilateral or/and multilateral through existing mechanism of UNFCCC. The developed countries preferred bilateral mechanism through existing financial institutions (Shamsuddoha and Chowdhury 2008) while developed countries voiced concern about bureaucracy of such mechanism. The COP13 also decided, for the first time, mitigation for the developing countries under long-term cooperative action together with adaptation supported by financing, capacity building and technology, which should be in a measurable, reportable and verifiable manner.

Meanwhile the "the Finance Minister's meeting" of the G8 countries, held in Osaka in June 2008, agreed to the "G8 Action Plan for Climate Change to Enhance the Engagement of Private and Public Financial Institutions". They also supported the launch of new Climate Investment Funds (CIFs) by the World Bank, which will complement existing bilateral and multilateral efforts, until a post-2012 framework under the UNFCCC is implemented (Shamsuddoha and Chowdhury 2008). The financing will be in the form of credit enhancement and risk management tools, such as loans, grants, equity stakes, guarantees and other support mobilized through donor contributions to the respective trust funds, which will be implemented in collaboration with the regional development banks (RDBs).

The Pilot Program for Climate Resilience (PPCR) was approved by the SCF Trust Fund Committee of the WB in 2009. The WB later named three countries, Bangladesh, Niger and Tajikistan to receive support with US$270 million from PPRC. The WB has also approved US$110 million for PPCR in Bangladesh, of which UD$50 million is in the form of grant and US$60 million in the form of credit.

Table 20.1 Chronology of key climate change milestones 2005–2010 within international and national context

International political and climate change related events	Bangladesh national events	Bangladesh climate change related events
• IPCC AR4 (2005) • COP13 at Bali (2007) • IPCC got noble prize (2007) • UK domestic politics Gordon Brown assumes office of PM (2007) • UK development minister issued a written statement on dispute over Bangladesh MDTF (2009)	• State of emergency imposed (2007) • Occurrence of two national scale flood and one category five cyclone Sidr (2007) • Top leaders of two big political parties arrested (2007) • CSRL formed with 200 national and international NGOs (2007)	• NAPA prepared (2005) • UK pledges 75 m GBP (2007) • Caretaker Government allocated BDT 300 Corer for climate change (2007) • BCCSAP process launched(2008) • 1st UK–Bangladesh Climate change conference held in Dhaka (2008) • MDTF design (2008) • BCCSAP launched in UK–Bangladesh climate conference in London (2008)
• Launched climate investment fund (2008) • COP 14 at Poznan, Poland (2008) • COP 15 at Copenhagen (2009)	• Equity BD adopted climate change (2007) • Bangladesh encountered severe food crisis (2007) • National election held (2008) • Awamileague led coalition with left parties formed government (2009)	• Finance advisor of Caretaker government declared World Bank to manage MDTF in 2nd UK–Bangladesh conference (2009) • Campaign in progress on demand of BCCSAP revision nationally and the UK (September 2008–March 2009) • New government make a total of BDT 700 Croer equivalent to $100 million annually under national climate change fund • Cabinet committee formed to review the BCCSAP; and cabinet formed to on expert committee to revise the BCCSAP (2009) • Cabinet approved revised BCCSAP (2009) • The climate change act passed in the parliament (2010) • Bangladesh signs loan from PPCR fund (2010). Climate Change Unit established in MOEF (2010)

20.3 Post Sidr Planning and BCCSAP

20.3.1 The BCCSAP

The BCCSAP was first developed during a state of emergency in Bangladesh in 2007 and 2008. The first version of the document which is referred to as BCCSAP 2008 (GoB 2008) was launched at the “UK Bangladesh Climate Conference” in

London in September 2008. Following the general election in 2009, the newly formed coalition government led by the Awami League (AL) revised and approved the current version of the document referred to as the BCCSAP 2009 (GoB 2009a).

The objective of the BCCSAP is to integrate climate change constraints and opportunities into the overall plan and programmes involving all sectors and processes for economic and social development. The document is prepared for only 10 years (2009–2018) and estimated US$5 bn for first 5 years for the implementation of selected adaptation activities. The document selected 28 cost effective priority programmes to be implemented in first 5 years (BCCSAP 2009). The document pursues an action plan with six following pillars:

(a) Food security, social protection and health,
(b) Comprehensive disaster management,
(c) Infrastructure development,
(d) Research and knowledge management,
(e) Mitigation and low carbon development,
(f) Capacity building and institutional development.

Putting finance and technology as means to achieve adaptation and mitigation the documented adopted a broad principle that "present day climate change is the result mainly of historical Green house gas emission by the western and other industrialized countries and finance has to come from them". Thus the document adopted a principle for adaptation funds that should be "purely grant basis".

20.3.2 Funds and Funding Mechanism

Post Sidr planning includes two funds and funding mechanism.

20.3.2.1 Climate Change Trust Fund (CCTF)

The *CCTF* is the Government's own trust fund generated from the national budget. The fund of Tk. 300 crores was initially declared by the Interim government in 2008 that was later increased to Tk. 700 crores (USD100 m) by the AL government. In early 2009, the Climate Change Trust Fund Policy was approved by the cabinet, and in May 2010, the Climate Change Trust Fund Act 2010 was passed to back-up the fund.

The MoEF formed three committees to facilitate the implementation of the fund; and established: (a) Interministerial Climate Change Steering Committee, (b) Climate Change Technical Committee and (c) the Trust Fund Board.

The MoEF called for proposals in November 2009 from GoB institutions and national NGOs to be funded by the CCTF. By January 2010, several projects were chosen; 17 were from government bodies and institutions and 7 by NGOs. Of the total amount of the fund, 66 % is allowed to be spent on activities and the remaining amount, 34 %, will be invested. This is according to the name of the Bangladesh Climate Change Trust Fund; the word "Trust" was specifically included for the purpose of keeping a certain amount of the annual allocation made in the budget towards the Fund for "investment".

20.3.2.2 Bangladesh Climate Resilience Fund (BCCRF)

Until recently the BCRF was called the Multi-Donor Trust Fund (MDTF). The origin of the MDTF was in the latter half of 2008 when the UK government pledged a grant amounting to 75 million GBP over the next 5 years to implement BCCSAP.

GoB singed communiqué with the UK in 2008 putting forward 2005 Paris Declaration on Aid Effectiveness through which UK support would be disbursed. Since UK's aid policy does not allow direct transfer to GoB's account, the MDTF was pursued as an alternative mechanism. Since creation of new institutions takes time, according to DFID, the WB came into the picture as a fund manager. Since then, the WB's role in the MDTF created significant national and international campaign and dispute between GoB and donors.

At the end of 2010, the utilisation of funds held in MDTF did not start while the final mechanism for the management and governance await approval from the Prime Minister of GoB. Until end of 2010, the EU, Sweden, Denmark and DFID joined in BCCRF.

20.3.3 Implementation Mechanism

BCCSAP establishes an organisational chart for coordination and facilitation of national actions on climate change:

(a) National environment committee, headed by the prime minister that is responsible for strategic guidance and oversight.
(b) National steering committee on climate change, headed by Minister of Environment and Forest, responsible for overall coordination and facilitation.
(c) Climate Change Unit, housed in MoEF, responsible for coordination and management.
(d) Climate change focal points in all ministries, reasonable for planning and implementing activities within their remit.

The government set up a Climate Change Unit in MoEF along with focal points in several ministries for coordination of all climate change activities (Bangladesh Development Forum Meeting 15–16 February 2010).

20.3.4 2012 Update of Climate Change Funding and Institutional Architecture

Climate Change policy operates in a competitive policy environment in Bangladesh. The government's priorities[4] at this time include Energy and Transport and are key drivers of economic growth. A brief review of energy and power policy revealed a

[4]http://www.thedailystar.net/newDesign/news-details.php?nid=187821.

dilemma for the country in that the reliance on dwindling stocks of Natural Gas, which is used for about 80–90 % of electricity generation is planned to be replaced by a significant increase in the use of coal as well as renewables. It is understood that National Coal Policy is currently being developed.

There is no exclusive national policy that deals with climate change in Bangladesh. The BCCSAP strategy does not specify which one, out of the 28 adaptation modalities, should be prioritised over the others and in which order the country implements such a long list of adaptation programmes. The absence of both prioritisation and costing should be addressed.

The development of climate change policy in Bangladesh has been stimulated and promoted by the international dimension. Reciprocally, Bangladesh has helped develop LDC positions and particularly contributed to debates on climate finance. Bangladesh's vulnerability in an international context has given it moral voice within an international context and it has championed the LDCs. In the longer term, the country's economic development may lead it into the middle income group-indeed that is a goal of political interests. This would mean it would benefit less from international funds.

The international and national institutions involved in Climate Change in Bangladesh represents a wide and complex constituency of interest that included Central Ministries, Line Ministries, Local Government, NGOs, the private sector and donor partners. Spurred on by direct experience of some extreme weather catastrophes, there has been increased focus on handling climate induced vulnerabilities in the light of climate change across the national political consensus. Some of the dynamism and energy has resulted in tangible outcomes with new national and sectoral policies and institutions being developed in recent years all of which included climate change concerns.

Bangladesh has not formulated a policy in relation to private sector involvement in Climate Change and has not set any target of preferred mix of funding or delivery modalities. This must be considered more fully in the development of a National Climate Fiscal Framework Development partners and Government have separated climate funding from mainstream Government planning and expenditure for their separate reasons. On the Government side the grounds are that current processes of assessment within the Planning Commission are slow and would delay spending.

The Ministry of Finance and the Planning Commission discussed inclusion of existing climate change funding into the public financial management systems in various occasions. BCCRF and the PPCR are avoiding the formal system and that this is against the principles of aid effectiveness, and that fiduciary risk cannot be an excuse to bypass national systems. However, as the Government's own Trust Fund also sits outside formal PFM systems of performance and scrutiny, there is clearly a need for movement towards accommodation of all funding mechanisms within existing PFM systems in Bangladesh—particularly in light of the already significant sums being processed through Government systems (Fig. 20.1).

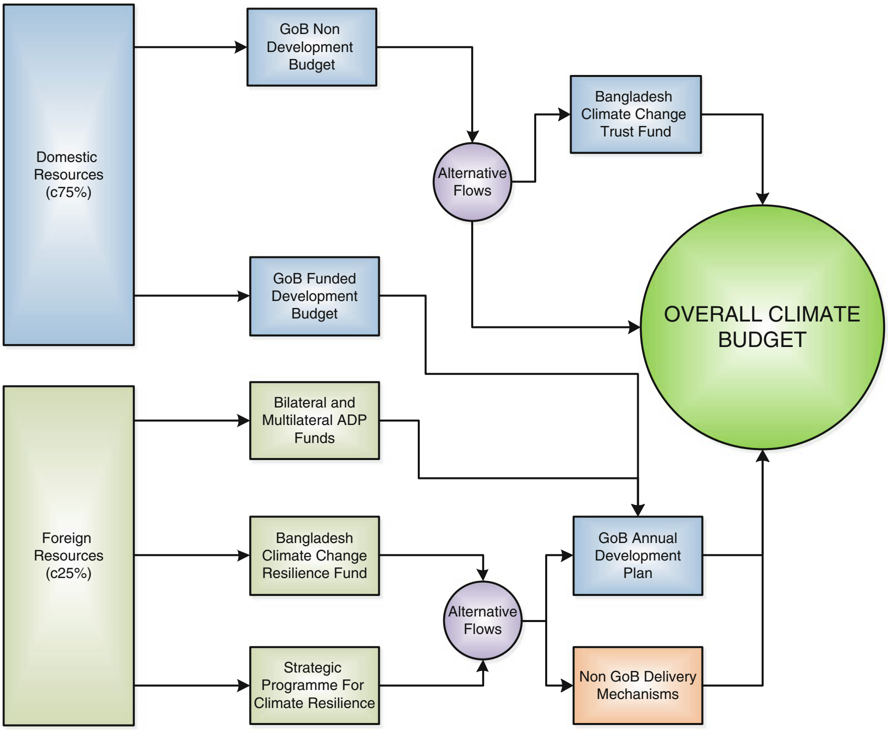


Fig. 20.1 Simplified overview of climate funds flow (Bangladesh). *Source*: General Economics Division (2012)

20.4 Process of the BCCSAP Planning

The formal process of BCCSAP formulation began in March 2008 and went through three distinct but connected phases until the current version was approved in March 2009. Each phase had distinct leadership, actors and dynamics (Table 20.2).

20.4.1 Phase One

This phase formally began in November 2007 when the Department of Environment (DoE) signed a Terms of Reference with the UK Department for International Development (DFID) for a policy support grant to develop the BCCSAP.

Crucially, this phase established the character of the formulation process by locating it within the environmental arena. According to DFID Bangladesh staff, the DoE was chosen because it was the main nodal point for climate change activities; the DFID and UNDP-funded Comprehensive Disaster Management Program had

Table 20.2 Major changes BCCSAP 2008 and BCCSAP 2009

Version	BCCSAP 2008	BCCSAP 2009
Key drivers	Previous technical studies including NAPA 2005	Political commitment of the AL government
Key principles	(a) Wide range of funding sources (b) Linking adaptation and mitigation: low carbon development as part of climate resilient development	(a) Funding should be grant only (b) Low carbon development without compromising economic growth (c) Recognising the historical responsibility of developed countries
Programme of action	120 programmes proposed. Predominantly techno-managerial actions including physical infrastructure, technical research and development, technology development, and institutional capacity. Only nine programmes for human capacity development	No significant change in the distribution of actions but additional programmes including planned migration, investment in women's capacity building, and river dredging

previously established a Climate Change Cell[5] within the DoE. DFID did not have contacts within the MoEF at that time although they kept MoEF informed about the process (DFID, personal communication, 2010). A staff member of the Climate Change Cell was assigned to design the programming aspect (CCC, personal communication, 2010) while the Economic Relations Division (ERD) of the GoB was asked to produce a financing mechanism for implementation of the BCCSAP. A document was produced to be shared with stakeholders by March 2008.

The MoEF and a few influential climate change experts not involved in this process questioned whether the DoE had the "mandate" and "capacity to formulate a strategy of a multi-sectoral nature". MoEF then assigned a group of experts to formulate the Strategy.

20.4.2 Phase Two

This is the core BCCSAP formulation process, which began in March 2008 and marked the launch of the first version of the BCCSAP in London at the "UK–Bangladesh Climate Conference" in September 2008. The key character of this phase was the involvement of a broader range of stakeholders. GoB announced an allocation of Taka 300 crore (USD 100 million) per annum from the national budget to

[5]Climate Change Cell was established in 2004 in the DoE under the Comprehensive Disaster Management Programme (CDMP) of GoB, UNDP and DFID. The purpose of the CCC was to enable the management of long term climate risks and uncertainties as an integral part of national development.

implement the BCCSAP. UK's pledge of GBP 75 million over 5 years came together with the idea of a World Bank (WB) led MDTF to govern, manage and mobilize the finance.

This phase saw a growth in debates and campaigns nationally and internationally over the process and content of BCCSAP, as well as the increasing involvement of the WB in the MDTF.

20.4.3 The Final Phase

This phase began when the AL led coalition government took notice to and engaged in the debate over the BCCSAP and MDTF in the beginning of 2009. The government set up a ministerial committee led by the Planning Minister to redevelop the BCCSAP (GoB 2009b) which highlighted key gaps in the document. The Cabinet put together a review committee comprised two previous members involved in phase two and a few new experts.[6] The committee recommended a draft BCCSAP in August which the cabinet approved and renamed as the BCCSAP 2009 in October. Meanwhile, the proposed role of the WB in the MDTF governance and management sharply divided the actors and created a dispute between GoB and donors, most notably the EU and DFID. The centre of the dispute was on the management of the MDTF. While GoB states that it had capacity to manage fund and donors insisted for WB to manage the fund that they thought would help mobilising more funds. This dispute was later declared to be resolved in the Bangladesh Development Forum (BDF) meeting in 2010.[7]

20.5 Actors and Their Ideology in Post Sidr Planning

A range of groups were involved in the different phases of the BCCSAP formulation process and subsequent debates. A summery is provided in Table 20.3.

20.5.1 Political Parties

The participation of the political parties in climate change issues remained almost nonexistent at the beginning of the BCCSAP formulation process, with no visible party positions expressed.[8] This was partly because of the state of emergency that

[6] A six member committee comprised of both GoB and experts.
[7] See Ed Milliband's statement to the UK Parliament, http://www.publications.parliament.uk/pa/cm200910/cmhansrd/cm100302/wmstext/100302m0002.htm.
[8] Based on the analysis of the participants list of the consultation workshop and confirmed by personal communication with a number of national political leaders.

Table 20.3 How actors influenced post Sidr planning

Major actors	Role in post Sidr climate change planning	Major tools used to influence the planning	Geographical influence	Relationship and configuration
Political parties in phase III	• Shifting the planning to political stream • Setup cabinet review and select experts for BCCSAP 2009 • Include AL's election commitment • Negotiated with donors to secure power over and shaped to MDTF management and governance	• Administrative and political procedure • Issuing formal statements nationally and internationally	National and international	Maintained formal and critical engagement with all actors. The campaign groups had access to key leaders AL
Civil bureaucrats	• Selecting experts in phase I and II • Led negotiation with donors and WB on MDTF and loan agreement in phase III	Administrative procedures	High national influence	Civil bureaucrats worked fairly independently with donors and experts in phase I and II and politicians in phase III
Experts	• Formulating and deciding on BCCSAP content and programmes in phase I and II; and shaped BCCSAP 2009 in Phase III	• Maintenance of relationship with MoEF officials through regular knowledge support • Connection with top government ministers, including PM in phase III.	High national influence in all phases. Connected to the donor communities	Civil bureaucrats and donors in phase I and II. The campaign groups had access to some experts in phase III selected by AL government as they share common ideology

Campaigns	• Pursuing climate justice discourse and raising criticism on the process and content of climate change planning • Demanding revision in BCCSAP process and content • Criticised and pursued WB role in MDTF governance • Pursuing an agenda of no-loan for climate change	• Publishing policy briefing • Writing letters to UK and GoB officials • Use of national and international media • Engage international campaign groups and Diaspora community • Street activism • Personal persuasion	Moderate at international and national level	Access to and influence over key experts, minister and top planners in government. Worked closely with media and politicians in all phases
Donors and lending agencies	• DFID provided financial assistance and support launching of BCCSAP • Pursued and negotiated with GoB on WB role in MDTF • Pursuing and signing loan agreement from PPCR with GoB • Some influence over selection of experts in phase I and II	Formal communication with GoB, donor coordination and diplomacy	High at international and national	Worked closely with bureaucrats in all phases and experts in phases I and II
Media	• Publishing views of all actors • Some media published independent items on BCCSAP, WB role in MDTF and loan issues	Part from regular news items, published editorials and special issues	Domestic high	Worked closely with campaign groups

set a limit to political activities and partly because they were not invited in various formal consultations workshops organised for the BCCSAP. The leading role of political party-only the ruling party in the process began in the phase three discussed in earlier section.

Like regular policy making process in normal (contrast to state of emergency) circumstance, role of opposition political parties were negligible in the BCCSAP building process in phase three. Professor Rehman Sobhan explains this as a pattern—"power configuration in Bangladesh is such that opposition political parties often fail to influence the policies in Bangladesh" (Sobhan 2007). Clearly, there was no major political debate raised by the political parties in all phases and climate

Box 20.1 Climate Change Text from Awami League 2009 Election Manifesto

"All measures will be taken to protect Bangladesh - including planned migration abroad - from the adverse effects of climate change and global warming".

"An integrated policy and plan will be formulated to protect the country from the adverse effects of global warming … Projects will be undertaken for river dredging, water conservation, flood control, prevention of river erosion and protection of forestry. Attempts will also be made for restoring and maintaining ecological balance. Initiatives will be taken to implement the Ganges barrage project to expand irrigation facilities, prevent salinity and to solve the problem of scarcity of sweet water in the Sundarban region".

change is still at the periphery of the domestic politics. While the main opposition party, Bangladesh Nationalist Party (BNP), was less visible in pursuing agenda or alternatives, some of the key party leaders expressed their opinion on BCCSAP in the press and seminars organised by civil society groups, even in the state of emergency. This was perhaps due to limited party-wide "consensus" on the key climate change issues with an exception to AL that included climate change in their manifesto for 2009 general election (Box 20.1).

20.5.2 Civil Bureaucrats

The civil bureaucrats were a consistent powerful actor over the entire period of formulation. This is not unusual in policy making processes as they bear the sole responsibility in the preparation of major policies (Aminuzzaman 2002). During phase one and two, they assigned experts and approved their inputs for the BCCSAP. Such role was assumed by the cabinet,[9] which is ultimate authority of approving a policy (Aminuzzaman 2002), once AL came into power.

[9] As per the clause of the Rules of Business 1996 clause 4, "no important policy decision shall be taken except with the approval of the cabinet" (Aminuzzaman 2002).

Bureaucrats within the government do not necessarily share common ideology and policy position; often reflect the ideology of ruling government. There was a change in the civil bureaucracy, especially in MoEF once AL came into power. The new bureaucrats played a visible role in the negotiations with donors on the governance and management of the MDTF. Bureaucrats were also divided over key policy issues that was reflected when Ministry of Finance signed a loan agreement with the WB while MoEF was clearly not favour of loan.

20.5.3 Community of Experts

The community of experts in the BCCSAP process was comprised of the country's senior economists, engineers and environmentalists. The individuals in this actor group formed a community through their historic engagement in the technical issues of environment, water management and poverty. Although fairly small in number and based in the capital, most of them played important roles in past environment related policy and strategy making process. They have strong views about what to do, as well as sharp differences over some policy issues, such as whether infrastructural solutions are the best option for flood management.[10]

This actor group is closely linked to international institutions and share a common incentive structure. Almost all of them had strong desire to retain their position and leadership over climate change issues. Many of them saw a "window of opportunity" to engage themselves in this historic process as well as wanted to see their ideas reflected in the document.

Experts from different sectors, engaged by the government, play important role in the policy and planning process of Bangladesh. Partisan preference over selection of experts for policy making by different regime is an important feature in recent policy making effort in Bangladesh.

20.5.4 Campaigns

The third influential set of actors is the **internationally connected campaign groups.**

Political parties led major campaigns in the recent past to influence policy agenda and pursuing alternatives in Bangladesh. This trend has been alerted, arguably since 1990s, when NGOs and civil society (both externally funded and home grown) started to play an important role in influencing policy agenda. The NGOs led campaigns and advocacy initiatives emerged in the context of wider adoption of right based and governance approach adopted by major donors and international NGOs.

---

[10] At least two of the key members of BCCSAP formulation in phase two and three had strong differences in view about the effectiveness of infrastructural solution to disaster problem in Bangladesh.

On the other hand, a number of citizens based environmental campaigns, exception to NGO model, emerged as powerful actor in the general environmental issues, especially in the area of conservation. Bangladesh Poribesh Andolon (BAPA) and Poribesh Bachao Andolon (POBA) influenced public opinion and pursued conservation at the centre of policy discourse. Climate change was not the central agenda of the campaigns although activities BAPA organised number of events on climate change at the beginning of 2000. This space was later filled through emergence of two campaigns in the context of global climate justice movement, international climate negotiation and politics.

Two major groups that have played an influential role in the second and third phase of the BCCSAP process are the *Equity and Justice Working Group*[11] (EquityBd), which is a coalition of national NGOs, and the Oxfam-led *Campaign for Sustainable Rural Livelihood* (CSRL). Networked with global climate justice campaigns,[12] they mobilized significant public opinion around climate change issues by organizing national and international events involving influential politicians inside and outside the government in the UK and Bangladesh. With change of communication technology, both the campaigning traditions engaged Bangladeshi Diaspora in the Europe.

20.5.5 Bilateral and Multilateral Donors

The fourth group is the community of bilateral and multilateral donors. The donors have historically played a significant and noticeable role in injecting ideas in public policy (Aminuzzaman 2002) and increased significantly in the recent years (Quibria 2010) although flow and importance[13] of aid as a proportion of GDP continue to decline in recent years[14] (Duncan et al. 2002; Quibria 2010). Among the multilateral lending agencies, the WB as the largest lender to Bangladesh has a significant influence over the policies in Bangladesh and promoted two decades of economic reforms (Sobhan 2002; Quibria 2010). Among the bilateral agencies, DFID is the

[11] www.equitybd.org.

[12] Including through Christian Aid, World Development Movement, Friends of the Earth, Jubilee Debt Campaign.

[13] Quibria (2010) views that although annual flow of aid has ranged from USD 1 billion to USD 1.5 billion its importance has declined due to increase in foreign exports and inward workers remittance. For example 1970 to early 1990s the aid was about 6 % of GDP while it stood to 2 % in 2005.

[14] Aid flows constitute less than 2 % of GDP, less than one-half of the annual development budget, and less than 20 % of total GoB expenditure. The comparable figures for the early 1990s were around 10 %, 100 % and 50 % respectively (source: B. Sundstrom, DFID). Thus, today aid disbursements are around 60 % of remittances to Bangladesh by our overseas migrant workers (Sobhan 2002).

largest donor to Bangladesh, and provided financial assistance to GoB to formulate the BCCSAP[15] (House of Commons International Development Committee 2010). DFID played the lead role in shaping and negotiating the role of MDTF.

20.5.6 Media

Bangladesh has a reasonably well developed and free media that played a significant role in shaping the public opinion and debate over climate change issues, especially in promoting the idea that MDTF to be managed by the government. Although the media did not assume an independent policy position themselves, they publicized the policy positions of the campaign groups. Surprisingly and unlike any other policy making process (Aminuzzaman 2002), the role of national and international NGOs was less visible in the BCCSAP planning process than is usual for major policy and planning ventures in Bangladesh.

20.5.7 Vulnerable Communities

The direct involvement of the **most vulnerable people** was largely absent involved in the process of BCCSAP formulation. Many of the key members of the drafting committee believed that the communities' views have been reflected in the BCCSAP as it took note of the learning from the NAPA which was written after consultation meetings were held in key regions. During the second phase, a group of invited NGOs and members from the civil society, academia, local and national government, and donors participated in three consultative meetings organized in Dhaka; but their role was limited in raising issues and commenting on the draft.

20.6 What Role Did Ideology Play in Shaping the Positions of Actors?

The study does not provide conclusions about the relative importance of ideology and material interests in shaping actors' policy positions and raising ideas and alternatives. But the presence of a number of ideologies is clearly visible in the BCCSAP as well as its building process.

The **pluralists** include part of the bureaucrats and expert community. They assume that the liberal planning process creates an environment for all interest

[15] DFID's programme there in the current financial year is £125 million and will rise to £150 million in 2010–2011, making the UK the largest bilateral donor.

groups in the society to influence the planning process. As a consequence, specific measures may not be necessary to involve the most vulnerable section of the community. As a result involvement of local NGOs was seen as a substitute for the direct involvement of the vulnerable people in the planning.

The **modern climate justice** is a descendent of the trade justice ideology and is the most influential ideology shared by individuals and institutional actors within governments, campaigns, media, some of the community of experts and donors. The key interpretation of the ideology is of Bangladesh's right to new and additional resources from international sources to help tackle the causes and effects of climate change with those for adaptation in particular regarded as "compensation" for damages caused by emissions largely generated elsewhere. Visible at international nature of mobilisation and management of resources the ideology was less translated how resources to be distributed to various vulnerable groups in the country.

The **left ideology**, although less visible but influential in debates and discussions in BCCSAP process, has a historical root in opposing the role of international financial institutions in domestic policy making. Journalists in Bangladesh who raised issues on the BCCSAP process and content in the second phase are known as left-leaning. Bangladesh has a historical presence of strong left political parties until the fall of the Soviet Union. The socialist character of AL and the ruling coalition is shaped by the joining of influential leftists in AL as well as left parties in the coalition. Many experts interviewed by the research team believed that the coalition government's opposition to the WB role in MDTF and refusal of loans for climate change until 2009 was a reflection of both the left and climate justice ideologies. Some of the biggest contemporary campaigns especially in relation to natural resources and energy are organised by left political parties and intellectuals.

The **faith based ideology** found especially within the Islamic and Christian traditions. Christian ethics have heavily underpinned notions of climate justice both international and in Bangladesh, particularly through the NGO movement and its advocacy. While Islamist ideology has been influential in translating major policy ideas such as education policy, land rights and women's issues in Bangladesh, they played a very limited role in the BCCSAP process.

Market liberalists have been crucial in promoting the idea that a mix of grants and loans is an essential element to finance efforts to tackle climate change. This ideology is shared by the multi lateral development banks, a part of government bureaucrats and part of community of experts. These groups also believe that aid effectiveness as a global standard is the most important component of the management and governance of climate change grants.

The combination of the pluralist, market liberalist, climate justice and left ideologies had an influence in raising debates throughout the BCCSAP process. As an outcome, the climate justice ideology resulted in a prolonged campaign in Bangladesh and Europe. The influence of market liberals translated into GoB's acceptance of the WB role in MDTF and signing of a concessional loan agreement between GoB and WB.

20.7 Contested Ideas in the Planning

This section first presents a list of key ideas generated in the climate change planning process. Then it provides an analysis of how ideologies and shifting discourses coupled in producing contested ideas that shaped BCCSAP process.

(a) CC planning is more effective if pursued within general development planning vs. special planning within climate change arena and MoEF.
(b) Specialists driven top down vs. a bottom-up process involving the most vulnerable communities.
(c) Techno-managerial approach vs. programme for human capacity building.
(d) The climate change fund as compensation vs. concessional loan.
(e) Creation of special financing mechanism i.e. MDTF managed by the WB vs. Bangladesh's control over the fund management.

20.7.1 Specialised vs. General Development Planning

The Planning Commission is the central planning body of Bangladesh responsible for macro and micro economic plans and policies i.e. National Five Year Plan and Annual Development Plans. According to the GoB's Rules of Business, the ministries are responsible for the sectoral policy formulation, planning, evaluation and execution (Aminuzzaman 2002). Unlike policy making, Bangladesh does not have any formal process for strategy development (Chowdhury 2003).

Planning experts interviewed raised the question whether a faster and sustained mainstreaming of climate change into the country's central planning process can be achieved if it was done through the national planning process and its institutions. The root of this question rests on the analysis that development can increase vulnerability thus both climatic and non climatic factors are to be included into the climate change planning for it to be effective. BCCSAP acknowledges mainstreaming as a means to address multi-sectoral nature of climate change problem. However, the ownership as prerequisite for mainstreaming has been weakened due to BCCSAP's location within a sectoral ministry. For example, the Finance Ministry signed a loan agreement[16] with the WB under PPRC while BCCSAP stated against taking loans.

Interviewed experts concern about likelihood of creation of planning exceptionalism since the implementation of BCCSAP may not go through regular national planning appraisal, approval and financing process. For example, two different governance and management infrastructures have been created for appraisal,

[16] World Bank approved a 110 million PPCR project on November 10, 2010. In the presence of WB and DFID, ERD on behalf of the GoB signed the agreement in which USD 50 million is grant while USD 60 million is concessional loan.

approval and monitoring of projects under the BCCSAP. The first is for projects which will be financed by the National Trust Fund, and managed by the Climate Change Unit in the MoEF. The second is for projects to be financed by the MDTF, and governed and managed by an evolving new system with the involvement of GoB, participating donors and the World Bank as administrators.

20.7.2 Top Down vs. Bottom-Up Process

The BCCSAP by design is a specialist driven process and did not involve the most vulnerable communities affected by climate change (Raihan et al. 2010; Khaled 2009). Moreover, the DFID funding for the development of BCCSAP did not include any activity and spend for involving these groups.

Many involved experts provided a number of explanations on why community involvement was non-existent in the BCCSAP process. They all univocally said that they had limited time to produce such a massive document in 6 months to be launched in London in September 2008. An expert commented that “the document could have been much nuanced and effective had there been more time for consultation”. A second reasoning is an assumption that there is a limit to climate change knowledge that experts are aware of which community consultation would not substantially alter the content that reflects the pluralist ideology of policy making. The third point was related to the justification that the community consultation was substituted by the inclusion of analysis and studies done during the NAPA preparation. The BCCSAP was finalized with three day-long workshops separately with government ministries, civil society members and donors respectively. Such process was heavily criticised by the campaign groups, media and politicians. For example the current Finance Minister stated that “the representation of the people who are vulnerable to climate change should be included in fund management and developing the climate change strategy paper” (The Daily Star 2008).

20.7.3 Techno-Managerial vs. Human Capacity Building

The country’s wealth of development knowledge especially in disaster, water and environment arena was transformed not only as evidence of climate change but also to narrate what should be done to adapt to its impacts. For example, the post Hyogo disaster analysis put social and political aspect of vulnerability at the centre of policy and practice of disaster risk reduction. Although engineering solutions to the disaster problem has always been controversial in Bangladesh, informed interviewees argued that the BCCSAP should have been built on the past lessons from infrastructural projects on disaster management especially from Flood Action Plan in 1990s (Lewis 2010).

The second debate was centred on the inclusion of mitigation in the BCCSAP. The donor community hailed the inclusion of low carbon development as a pillar in the BCCSAP which caused debate among the campaigning groups in Bangladesh. The UK Bangladesh communiqué declared in London states that UK is committed to Bangladesh to switch to a low carbon development path and reduce its dependence on ever more expensive fossil fuel. The New Age daily published an editorial urging that low carbon technology must not be obligatory which will necessarily thwart and impede the progress of the poor countries (NewAge 2008b). The ruling AL government later adopted two principles: (a) mitigation measures should be supported by finance and technology by the developed countries, (b) this mitigation activities should not affect the country's sustainable development growth.

20.7.4 *The Climate Change Fund as Compensation vs. Concessional Loan*

There was considerable frustration[17] among actors about too little fund Bangladesh received till 2007.[18]

This frustration promoted the idea that Bangladesh could accept concessional loans from lending agencies fearing that Bangladesh would not receive adequate amount of grants (GoB 2009b). Following the huge economic loss resulting from the 2007 disasters, the GoB and Bangladesh's campaign groups shaped the idea of claiming compensation. The Prime Minister and Foreign Minister expressed similar positions in the past. In 2009 before COP15, the Foreign Minister Dipu Moni said "Copenhagen conference must agree on funding grants and not loans" (Daily Star November 2009). At the same time Bangladesh's newspapers ran another story saying "the ERD is pursuing for loan based MDTF sponsored by the WB while the MoEF was opposing the division's plan on the grounds that it contradicts Bangladesh's stance with the LDCs and G77 in the global climate negotiations" (NewAge 2008c).

20.7.5 *Special Funding Mechanism i.e. MDTF Managed by the WB vs. Bangladesh's Control Over the Fund Management*

The communiqué signed between the GoB and UK states that "the UK support will come with 2005 Paris declaration of aid effectiveness aligning it to government owned plan through a Bangladesh Multi Donor Trust Fund and the UK will

[17]GoB and the national and international civil society expressed such frustration reported in national and international newspapers. Prime Minister of Bangladesh also expressed such concern in many occasion including GCC meeting in Dhaka.

[18]Till 2007, Bangladesh only received 250 million USD through GEF for implementing the NAPA.

continue to work with GoB and other development partners to make MDTF operational". During the conference the then Finance Advisor made a comment that the WB may be given the responsibility to manage the fund which was opposed by the Special Assistant to the Chief Advisor of Environment (NewAge 2009).

The idea of WB's involvement in the MDTF can be traced back to DFID's assessment over the risk of transferring the responsibility of the financial trust fund directly to the government (House of Commons International Development Committee 2010). Direct Budget Support remains off limits for the EC, in view of continuing governance challenges and weak Public Finance Management (Global Climate Change Alliance). DFID told the study team that creating a new institution for managing the MDTF could have been time consuming and expensive. However, the idea of WB's involvement as administrator created a significant campaign in Bangladesh and Europe, and a huge dispute between the government and sponsoring

Box 20.2 Dispute Over MDTF

Following are the major disputes over MDTF:

(a) GoB views that it has the capacity to manage the fund and wanted donors to transfer the fund directly to the government. The donors wanted WB to provide the administration of fiduciary part of the MDTF while government thought WB can only provide technical backstopping and skill transfer role. GoB stated it can ensure robust fiduciary risk oversight mechanism. GoB and campaign groups stated WB role in MDTF as an idea opposing the national ownership enshrined in the UNFCCC.

    Civil society groups argued against WB management—high fees of consultants: Civil society groups, both in Bangladesh and the UK argued that WB hired international consultants that charged high fees. The costs of the WB management would amount to 10–15 % of the funds (which would be over 4 million GBP of the initial offer of 50 GBP). That amount of the fund would not trickle down to the most vulnerable people for which it was intended.

(b) GoB proposed to establish its independent governance and authority, and a three-tier governance structure, while the donors wanted to appoint the WB as an independent trustee to the fund. The WB wanted the MDTF to be governed by the terms of the legal agreement between the Bank and the donors.

(c) The third dispute was about the sources of finance. The major concern was whether the bilateral fund pledges from the "Annex 1 countries" (UNFCCC) to the MDTF is new and additional to the existing ODA commitments or not. It was campaigned by the CSOs that the donor's commitment to the MDTF is from their existing aid budget to Bangladesh, instead of being additional money, which is a breach of the financing commitment made under the UNFCCC.

donors (Box 20.2). The Minister of Environment pointed out at the Bangladesh Development Forum (BDF) meeting that "the fund would be administered by the government while ensuring robust fiduciary risk oversight mechanism satisfactory to the development partners" (GoB 2010). The 3 year long dispute resulted in a number of changes in the management and governance of the MDTF.

WB's role in MDTF overshadowed the discussion on the content and process of BCCSAP during the second and third phases.

20.8 Concluding Remarks: Further Reflections

Bangladesh's experience demonstrates a number of key lessons in the political economy of climate change planning. Understanding these patterns has important implications on the future climate change planning and their implementation in Bangladesh and other vulnerable countries.

The first lesson is related to the planning approach that can foster and sustain the mainstreaming of climate change into the central development planning. There is always a risk of creating special planning and implementation process referred as planning exceptionalism parallel to existing planning and approval process. A number of challenges emerged from Bangladesh Case Study.

- The first of the key challenges remains with the application of aid effectiveness by the donor countries. Donors often adopt short-term approaches to achieve aid effectiveness by creating alternative mechanisms of planning and implementation risking sustainable mainstreaming of climate change with the overall development planning and implementation.
- The second challenge is domestic in which specialization of climate change arena merits further reflection. The key question to be asked is whether climate change should remain in a specialized sphere led by technical experts or opened up to include actors from all different sectors, population groups and settlements.

The second lesson is related to a wider question of how a society should solve a transnational problem of a significant nature considering the unequal power relations between various actors in which planning and implementation takes place. While there has been a shift from state monopoly over the planning towards a participatory approach, the assumption of equal power of various actors and interest groups continue to persist among the policy elites in Bangladesh. As a result, NGO participation is often assumed to be a substitute for the involvement of vulnerable communities. Specific measures to empower the vulnerable people are a precondition of equitable policy making process and a just outcome.

The third lesson is related to application of climate justice idea and ideology. BCCSAP did not adopt a justice-based framework how various groups of vulnerable people would be benefited from the climate change planning, which the study team believes an unimplemented priority for Bangladesh. To address this shortcoming, study team recommends immediate development of a framework that must outline how resources would benefit not only existing various vulnerable groups but also the people who have already been affected by climate change.

The fourth batch of lessons is related to the design of policy, plans and programmes to tackle climate change. Experts often pursue solutions ignoring the past lessons especially in relation to upscale of existing interventions. Clearly inadequate time for building a long term strategy was a challenge for the actors involved in the BCCSAP. The lack of domestic politics in climate change and limited involvement of parliament resulted in limited debate and accountability of the planning process. Whether Bangladesh should take loans for climate change should have been debated in the parliament. The challenges that need to be addressed are the following:

- A political ownership of all parties is a necessary precondition to protect the country from climate change impact. Government should provide leadership to create such a precondition. Parliament's role should be made mandatory to formulating vital policy and plans.
- Institutional ownership on the planning process is also a precondition for mainstreaming BCCSAP into the national sectoral and planning process. The role of inter-ministerial body is vital for understanding of barriers for mainstreaming and creating enabling environment for promoting ownership over change processes required for climate resilient development.
- Local government must play a vital role in implementing climate resilient development, which is an overlooked area of the BCCSAP that needs to be considered.
- The mega infrastructural projects included in the BCCSAP should be critically examined in light of past lessons especially Flood Action Plan (FAP) and Coastal Environmental Project (CEP) of 1960s and future trends before they are implemented.
- GoB should establish a robust accountability mechanism that has ownership and trust of all actors for the utilisation both national and international resources.

References

Aminuzzaman S (2002) Public policy making in Bangladesh: an overview. Public Money Manage 2 (June)

Barnett MN, Finnemore M (2004) Rules for the world: international organizations in global politics. Cornell University Press, New York

Chowdhury K (2003) The process of policy and strategy formulation. Working paper 020. Program Development Office for Integrated Coastal Zone Management Plan (PDO-ICZMP)

Dessler AE, Parson EA (2006) The science and politics of global climate change: a guide to the debate. Cambridge University Press, New York

Duncan A, Sharif I, Landell-Mills P, Hulme D, Roy J (2002) Supporting the drivers of pro-poor change. DFID, Bangladesh

General Economics Division (2012) Public expenditure for climate change. National Planning Commission, Bangladesh, p 66

Giddens, Anthony (2008) Politics of Climate Change. Policy Network, London

GoB (2008) Bangladesh Climate Change Strategy and Action Plan 2008. Ministry of Environment and Forest, Government of Bangladesh, Dhaka

GoB (2009a) Bangladesh Climate Change Strategy and Action Plan 2009. Ministry of Environment and Forest, Government of Bangladesh, Dhaka

GoB (2009b) Meeting Minutes of the Ministerial committee formed to review BCCSAP. Ministry of Environment and Forest, Dhaka

GoB (2010) Meeting minutes of the Bangladesh Development Forum

House of Commons International Development Committee (2010) DFID's Programme in Bangladesh. Third Report of Session 2009–10. London

Kingdon JW (2003) Agendas alternatives and public policies, 2nd edn. Longman, New York

Levy DL, Kolk A (2002) Strategic responses to global climate change: conflicting pressures on multinationals in the oil industry. Business and Politics 4(3):275–300

Lewis (2010) Strength of weak ideas. Human security, policy history and climate change in Bangladesh. In: Security and development. Berghahn Books, Oxford, pp 113–129. ISBN 9780857451774

NewAge (2008a) Faces of change. Special issue on climate change. Dhaka (31 May 2008)

NewAge (2008b) Editorial. A questionable Plan Through A questionable Process

New Age (2008c) Climate change funds: Bangladesh Environment Ministry, ERD ad loggerheads-Ministry wants funds in grant, ERD wants in loans. Dhaka

NewAge (2009) WB's fingers in Bangladesh's climate fund pie. Internet Edition

Quibria MG (2010) Aid effectiveness in Bangladesh

Raihan M, Huq J, Alsted G, Andreasen H (2010) Understanding climate change from below, addressing barriers from above. ActionAid, Dhaka

Shamsuddoha M, Chowdhury RK (2008) Political economy of the Bali climate conference: a road-map of climate commercialization. South Bull (Geneva, Switzerland) (11)

Sifayet U (2008) An analysis of the formulation process of Bangladesh Climate Change Strategy and Action Plan (BCCSAP) 2008. Unpublished MSc Thesis. Department of Environment, London School of Economics, London

Sobhan R (2002) Political economy of the state and market in Bangladesh. Center for Policy Dialogue, Dhaka

Sobhan R (2007) Challenging Bangladesh's crisis of governance and agenda for a just society. Challenging injustice, an odyssey of a Bangladeshi economist. Center for Policy Dialogue, Dhaka, p 344

Tanner TM, Hassan A, Islam KMN, Conway D, Mechler R, Ahmed AU, Alam M (2007) ORCHID: piloting climate risk screening in DFID Bangladesh. Research report. Institute of Development Studies, Brighton, UK. Available at: www.ids.ac.uk/climatechange/orchid

Tanner TM, Allouche J (2011) Towards a new political economy of climate change, IDS Bulletin 43(3):1–14

The Daily Star (2008) Ensure people's representation, 2008-10–12

The Daily Star (2009) Victim nations must get grant, not loan: Dipu. http://www.thedailystar.net/newDesign/latest_news.php?nid=20509 (November)

Yamin F, Depledge J (2004) The international climate change regime: a guide to rules. Institutions and Procudures. Cambridge University Press, Cambridge

About the Editors

Rajib Shaw is an Associate Professor in the Graduate School of Global Environmental Studies of Kyoto University, Japan. He worked closely with the local communities, NGOs, governments and international organization, including United Nations, especially in the Asian countries. He is currently the Chair of the United Nations Asia Regional Task Force for Urban Risk Reduction, and the President of Asian University Network of Environment and Disaster Management (AUEDM). His research interests are: community based disaster risk management, climate change adaptation, urban risk management, and disaster and environmental education. He has published several books in the field of disaster and environmental management. He is also the Chief Editor of Asian Journal of Environment and Disaster Management.

Fuad Mallick is the Professor and Chairperson of Department of Architecture and Director of the Postgraduate Programs in Disaster Management (PPDM) at BRAC University. He did pioneering research on thermal comfort for Bangladesh and published extensively on it. He is the founder of the department of architecture of BRAC University and the author of its curriculum. He is also the founder director of the university's Post Graduate Programs in Disaster Management, the first of its kind in the region. Fuad's research background is on environmental aspects of architectural design, low income and rural housing, architectural education and in the last few years disaster management and climate change. He has written book chapters and published journal articles on disaster management and climate change issues. He has been a reviewer for the Aga Khan Award for Architecture and a member of Aga Khan Education Program's thinking group for conceptualizing a School of Architecture and Human Settlements for the Aga Khan University. He is the Vice President of the Asian Universities Network for Environment and Disaster Management (AUEDM).

Aminul Islam is specialized in climate change, environment and disaster management and contributed as an academic, researcher, practitioner, manager and policy adviser. He is associated with United Nations Development Programme since 1996

R. Shaw et al. (eds.), *Climate Change Adaptation Actions in Bangladesh*, Disaster Risk Reduction, DOI 10.1007/978-4-431-54249-0, © Springer Japan 2013

and served different positions in Bangladesh Country Office started as the Sustainable Development Adviser and served as the Assistant Country Director and lead the Climate change, Environment and Disaster Management Cluster and currently Senior Adviser. Dr. Islam also served as the Senior Technical Adviser and Team Leader of the Water Disaster Risk Reduction Project in Central Vietnam supported by UNDP Vietnam. As an academic, he taught research methodology for the post graduate programme in the Institute of Bangladesh Studies in Rajshahi University, founder Director and Associate Professor of the School of Environment Science and Management of Independent University, Bangladesh and also contributed as an Adjunct Professor of the Population Science Department in Dhaka University. He was Environmental Scientist of the Flood Action Plan's Component 16 on Environment implemented by the ISPAN (Virginia, US based) supported by USAID.