

**An International Geosphere-Biosphere Programme Synthesis
Theme on Global Environment Change and Sustainable
Development: Needs of Least Developed Countries**



An International Geosphere-Biosphere Programme
Synthesis Theme on *Global Environment Change and
Sustainable Development: Needs of Least Developed
Countries*

**Project Reference Number: ARCP2011-16NMY/ARCP2012-06CMY-IGBP
Final Report submitted to APN**

OVERVIEW OF PROJECT WORK AND OUTCOMES

Non-technical summary

With the scientific leadership of the International Geosphere Biosphere Programme (IGBP) and financial support from Asia-Pacific Network for Global Change Research (APN), scientists from Asia Pacific and Small Islands Developing States (SIDS) that are members of APN and fall under Least Developed Countries (LDCs) conducted a synthesis on Global Environmental Change (GEC) and Sustainable Development in the Asia-Pacific and SIDS LDCs. The synthesis was part of the IGBP second major international synthesis of key policy-relevant areas within GEC research that commenced in 2009 with wide consultation resulting in the identification of synthesis themes among which was a theme on “GEC and Needs of LDCs” that was launched in Maputo Mozambique, September 2010. The LDCs synthesis focused on natural hazards and disasters, human health and environment and the role of indigenous knowledge systems. The aim of the IGBP-LDCs synthesis was to facilitated engagement of LDCs scientists to enhance capacity and generate policy relevant information. Within this the Asian Pacific and SIDS LDCs synthesis covered marine environment, coastal zone management and climate change extremes such as droughts and flood and the potential role of indigenous knowledge systems in addressing these challenges. The Asia Pacific and SIDS LDCs synthesis was based on existing documented and non-documented knowledge and resulted among others in a special issue in the journal of Weather and Climate Extremes, policy briefs and information Dissemination Workshop, in Dhaka, Bangladesh. The synthesis process helped enhance cooperation across scientists, implementers and policy makers on managing environmental change among participant countries particularly in Bangladesh where majority of leading scientists were based. But the synthesis extended over a large spectrum of LDCs viz. Bangladesh, Nepal, Bhutan, Afghanistan, Cambodia, Myanmar, Yemen, Laos PDR, Kiribati, Vanuatu, Tuvalu, Samoa (graduated out of LDCs in 2014), Comoros and São Tomé and Solomon Islands.

Keywords: Flood, drought, marine environment, coastal zone management, climate change, weather extremes, traditional knowledge, policy, capacity building

Objectives

The main objectives of the synthesis project were:

1. To facilitate integration of local-national based knowledge with relevant global to regional outputs from international organizations and networks such as APN and GEC programmes e.g. IGBP , to help address pertinent policy needs in LDCs Asia and SIDS
2. Build capacity in cross-scale fertilization of scientific information among LDCs.
3. Identify new areas of research for further investigation at local and international level to advance the needs of LDCs
4. Enhance networking between LDCs, APN and global scientists from IGBP and its partners.

Amount received and number years supported

The Grant awarded to this project was: USD 90,000

US\$ 45,000 for Year 1

US\$ 45,000 for Year 2

Activity undertaken

The synthesis activities were undertaken within five sub-themes as follows:

- i. Barriers to Reducing Climate-Enhanced Disaster Risk in SIDS
- ii. Droughts in Environmental Changes and Sustainability of Asian LDCs

- iii. Challenges facing Bangladesh and Myanmar in Nurturing Marine Environment for Sustainable Development
- iv. Flood in the Context of Environmental Changes and Sustainability: Bangladesh and Nepal
- v. Coastal Zone Management in Bangladesh

Activities of the synthesis involved desktop review of published scientific findings and grey literature; information gathering and exchange through informal interactions, observations, field visits, to formal workshops, conferences, meeting and seminars (Table 1)

Table1. Summary of significant Workshops, conferences, seminars and meetings held and attended by country.

a. Activities organized:

Country	Description
Bangladesh	-Four field visits where the 4-sub-themes engaged in wide consultations with different key informants in different institutions -Four data gathering and information dissemination workshop in different academic institutions -One data gathering and information exchange workshop at Agriculture Research Centre -One final Policy oriented information dissemination workshop
Nepal	A field visit for the drought and floods sub-themes
Cambodia	A field visit for the drought sub-theme
Laos PDR	A field visit for the drought sub-theme
UK	Convened a session under the Planet Under Pressure international conference
Thailand	A write a paper workshop led by the Chief Editor of the Weather and Extremes Journal and the IGBP Vice Chair.
USA	Co-convening an Oral and Poster session at the AGU Fall Meeting 14-18 December, 2015

b. Activities attended by Principal investigators of sub-themes:

Bangladesh	Two workshops and a conference on climate change and coastal zones
India	Four climate change and disasters related consultative meetings
Japan	Two conferences related to Education for Sustainable development (ESD)
Pakistan	Two consultative and information dissemination meetings on disasters
Nepal	Consultative meeting on rapid response to floods
Korea	Two meetings on Oceanography and marine Meteorology
Kenya	One meeting of Global Regional Centers of Expertise Conference on ESD
Philippines	One meeting on Sustainable Development and Climate Change

Results

A. Scientific Research

1. Collected, compiled and interpreted scientific information, indigenous and traditional knowledge system for Asian and SIDS LDCs regarding drought, flood, climate enhanced disasters and adaptation and effects on coastal zones and marine ecosystems for use by various stakeholders including for UNFCCC LDCs and SIDS climate change negotiations
2. Published 10 peer reviewed papers in the special issue of the Weather and Climate Extreme Journal of Elsevier edited by Opha Pauline Dube and Mannava V.K. Sivakumar (SI: IGBP APN Volume 7 (2015))

3. Contributed to [the APN Science Bulletin, Issue 2, March 2012, ISSN 2185-761x, pp90-92](#)
 4. Produced Proceedings of the information dissemination workshop on Synthesis of the Needs of Asian LDCs in the Context of Global Environmental Change and Sustainable Development
 5. Developed findings that have been shared nationally and internationally through conferences and workshops etc.
 6. Enhanced capacity in science research, reporting and peer review process and exposure to regional and global environmental change knowledge base
 7. Developed skill and capacity in science research among four senior students
 8. Enhanced scientific paper writing capacity of three additional faculties that were originally not directly linked to the project resulting in additional publications and contribution to information dissemination workshop
 9. The project has opened scope for new research e.g. integration of traditional and conventional practice for long term solution to climate extremes
- B. Facilitated linkages between scientists and policy makers and produced policy briefs – available also in local language for Bangladesh (ISBN 978-984-33-9805-5)
 - C. Cooperation with many national and international organizations have been established
 - D. The project contributed to building up the bridge of cooperation with APN, IBGP, South Asian Association for Regional Cooperation (SAARC), International Centre for Climate Change and Development (ICCCAD) and Association of Management Development Institutions in South Asia (AMDISA)

Relevance to the APN Goals, Science Agenda and to Policy Processes

The synthesis is in line with major traits of the APN vision, mission and science agenda in the following ways: (i) by contributing to larger process of identifying, explaining and predicting changes in the context of both natural and anthropogenic forcing; (ii) by contributing towards assessing potential regional vulnerability of natural and human systems; and (iii) contributing information to the development of policy options for appropriate responses to global change for sustainable development among the Asian and SIDS LDCs.

Furthermore, this synthesis project has significantly contributed towards interactions between scientists and policy makers, providing scientific input to decision making process and disseminating scientific knowledge among the public. In addition, the process adopted in this project contributed to capacity building through learning by doing among the scientists of the LDCs who before had very limited exposure to regional and global knowledge base.

Self-evaluation

This synthesis project has met its goal of conducting a synthesis based on integration of local-national based information with relevant outputs from international and regional organizations bringing both scientific and traditional information valuable to establishing solutions to address environmental changes and vulnerabilities with respect to climate adaptation, drought, flood hazards and disasters, marine and coastal ecosystem in Asia Pacific and SIDS LDCs. The synthesis was conducted in close collaboration with policy makers and key stakeholders and gave opportunity to highlight the potential to integrate traditional knowledge into conventional practice. It produced products for both the science community and policy makers. By implementing the project through academic institutions the synthesis process provided the bases for long term sustainability.

Potential for further work

Further country level studies are necessary in all the sub-themes covered by the synthesis to reflect specific country policy perspective for vigorous action on mitigation and adaptation to deal with vulnerabilities induced by natural and human factors as well as climate change. Much traditional and local knowledge have been identified and require further in-depth investigation for scientific validation and wide scale dissemination. Indigenous strategies such as traditional defense mechanism, triple tier defense system of mangrove forest and deep water reservoir, identified as long term solutions to weather extremes, help open new dimensions to advance research in climate change adaptation and disaster risk reduction. This will contribute to national disaster management policies. Environmental challenges in the coastal and marine production zone signal the need for greater attention in management of these systems, i.e. the Bay of Bengal and its coastal areas are significant productive zones that are threatened by anthropogenic activities e.g. the fishing zones are shifting and production has been declining. Collective action by Bangladesh and Myanmar are required to keep the coastal and marine environment pollution free. Bangladesh owns huge marine economic zone for which extra management force has to be deployed. In the LDCs SIDS effort to strengthening governance and address the root causes of vulnerability will go a long way to addressing barriers to adaptation. The LDCS SIDS synthesis provide a useful baseline for measuring progress and success of adaptation efforts whilst highlighting policy areas that need further investments

Publications

1. Pauline Dube, O., & Sivakumar, M. (2015). Global environmental change and vulnerability of Least Developed Countries to extreme events: Editorial on the special issue. *Weather and Climate Extremes*, 7, 2–7. <http://doi.org/10.1016/j.wace.2015.03.003> .
2. Miyan, M. A. (2015). Droughts in Asian Least Developed Countries: Vulnerability and sustainability. *Weather and Climate Extremes*, 7, 8–23. <http://doi.org/10.1016/j.wace.2014.06.003>
3. Karim, M. R., & Rahman, M. A. (2015). Drought risk management for increased cereal production in Asian Least Developed Countries. *Weather and Climate Extremes*, 7, 24–35. <http://doi.org/10.1016/j.wace.2014.10.004>
4. Dastagir, M. R. (2015). Modeling recent climate change induced extreme events in Bangladesh: A review. *Weather and Climate Extremes*, 7, 49–60. <http://doi.org/10.1016/j.wace.2014.10.003>
5. Shohidullah Miah, M. (2015). Climatic and anthropogenic factors changing spawning pattern and production zone of Hilsa fishery in the Bay of Bengal. *Weather and Climate Extremes*, 7, 109–115. <http://doi.org/10.1016/j.wace.2015.01.001>
6. Dewan, T. H. (2015). Societal impacts and vulnerability to floods in Bangladesh and Nepal. *Weather and Climate Extremes*, 7, 36–42. <http://doi.org/10.1016/j.wace.2014.11.001>
7. Basak, S. R., Basak, A. C., & Rahman, M. A. (2015). Impacts of floods on forest trees and their coping strategies in Bangladesh. *Weather and Climate Extremes*, 7, 43–48. <http://doi.org/10.1016/j.wace.2014.12.002>
8. Ataur Rahman, M., & Rahman, S. (2015). Natural and traditional defense mechanisms to reduce climate risks in coastal zones of Bangladesh. *Weather and Climate Extremes*, 7, 84–95. <http://doi.org/10.1016/j.wace.2014.12.004>
9. Rahman, S., & Rahman, M. A. (2015). Climate extremes and challenges to infrastructure development in coastal cities in Bangladesh. *Weather and Climate Extremes*, 7, 96–108. <http://doi.org/10.1016/j.wace.2014.07.004>
10. Kuruppu, N., & Willie, R. (2015). Barriers to reducing climate enhanced disaster risks in Least Developed Country-Small Islands through anticipatory adaptation. *Weather and Climate Extremes*, 7, 72–83. <http://doi.org/10.1016/j.wace.2014.06.001>

11. Thoeun, H. C. (2015). Observed and projected changes in temperature and rainfall in Cambodia. *Weather and Climate Extremes*, 7, 61–71. <http://doi.org/10.1016/j.wace.2015.02.001>

Acknowledgments

The study was conducted with the financial support received from the Asia Pacific Networks for Global Change Research (APN) through the International Geosphere and Biosphere Programme (IGBP). Sincere thanks go to Dr Opha Pauline Dube for initiating this synthesis theme through IGBP and for coordination and guidance under the support of the IGBP secretariat in particular Dr Joao Morais and Dr Karen Smyth. Support was also received from the IGBP Regional Office in Brazil in the initial stages of the study. The Research Team thankfully acknowledges guidance provided by Dr Mannava Sivakumar in peer review publication that resulted in a special issue. The researchers also wish to sincerely acknowledge South Asian Disaster Management Centre (SADMC), IUBAT—International University of Business Agriculture and Technology for providing material support to the project and giving the opportunity to the researchers to carry out the synthesis research with international scientists. The synthesis authors are indebted to the various stakeholders who volunteered their time and information for the success of this synthesis project.

Preface

Despite the fact that the LDCs are most vulnerable to global environmental changes, limited work has been done on such vulnerability and the potential role of indigenous knowledge systems. This project brought together scientific communities mainly from Asian and SIDS LDCs to assess the global knowledge base and its applicability in LDCs particularly, on local coping mechanisms. The needs of LDCs are often overlooked. This synthesis reflected on contextual realities as well as research gaps emphasizing local and traditional knowledge for mitigation as well as adaptation to environmental climate change. This opens new windows of research for the young scientists.

Table of Contents

- 1.0. Introduction
- 2.0 Methodology
- 3.0 Results & Discussion
 - 1. Droughts in Environmental Changes and Sustainability of Asian LDCs
 - 1. Background
 - 2. Drought Occurrence in Asian LDCs
 - 2.1. Experience of South Asian LDCs
 - 2.2. Experience of Southeast Asian LDCs
 - 2.3. Experience of Middle Eastern LDC
 - 3. Impacts of Droughts
 - 4. Coping with Droughts
 - 5. Drought Vulnerability Reduction
 - I. A. Modeling Climate Change Induced Extreme Events including Drought
 - Drought
 - Flood
 - Sea Level Rise [SLR]
 - Cyclone
 - Challenges of Modeling in Bangladesh
 - I. B. Cereal Production and Drought Risk Management
 - 6. Policy Priorities
 - Deep water reservoir
 - Adaptation to Draught
 - Crop Diversification
 - Drought Resistant Crop Varieties
 - Indigenous Culture
 - Biofortified Cereals for Drought Management
 - Forecasting for Early Warning
 - Knowledge Gap on Drought
 - Modeling of Climate Change Extreme
 - Vulnerability Categorization
 - Sea Level Rise (SLR)
 - Cyclonic Extreme
 - Capacity Building

II. Challenges Facing Bangladesh and Myanmar in Nurturing Marine Environment for Sustainable Development

Dynamics of Marine Environment

Fish Resources in the Marine Environment

Fishing Grounds in the BoB

Marine Fisheries

Hilsa Spawning Pattern in the Bay of Bengal:

Catch Per Unit Effort (CPUE) in the Marine Environment:

Marine Fisheries in Myanmar:

Sea Food Products and Coral Reef in the Marine environment

Policy Priorities

Livelihood of people

Seasonal Occupation for Fishermen

Protecting Spawners

Marine Pollution

Hilsha Laboratory and Hatchery

III. Floods in the Context of Environmental Changes and Sustainability in Bangladesh and Nepal

Flood Occurrence in Asian LDCs

Experience of South Asian LDC (Bangladesh and Nepal)

Causes of Floods in Bangladesh and Nepal

Flood Impacts

Personal security

Buildings and Infrastructures

Crops and Animals

Coping with Flood

Policy Priorities

Standing Orders on Disaster (SOD)

Flood Shelter

Flood Resilient Housing

Environmental Impact Assessment

Community Integration

Choice of Plant

Plantation Site

Flood-Resistant Tree Crop

III. A. Flood and Forest Trees in Bangladesh

Choice of Plants

Policy Priorities

Standing Orders on Disaster (SOD)

Flood Shelter

Flood Resilient Housing

Environmental Impact Assessment

Community Integration

Choice of Plant

Plantation Site

Flood-Resistant Tree Crop

IV. Coastal Zone Management in Bangladesh

Introduction

Environmental Change: Natural and Anthropogenic

Methods and Practices for Reducing Calamities

Coastal Green Bel

Selection of Species and Methods of Forestation

Destruction of Mangrove Forest:

Industrial and Commercial Activities in the Coast

Traditional Adaptation Practices

Traditional Landscaping for Homes in the Floodplains:

Coastal Cities:

Coastal City Governance:

Policy Priorities:

Coastal Zone Management (CZM)

Defense Mechanism

Coastal Cities

Involvement of Stakeholders

4.0. Conclusions

5.0. Future Directions

References

Apendix

Conferences/Symposia/Workshops

Funding sources outside the APN

List of Young Scientists

Glossary of Terms

1. Introduction

1.1. Context of the study

The International Geosphere-Biosphere Programme (IGBP) launched its second major international synthesis of key policy-relevant areas within global environmental change (GEC) research in 2009. The goal of the 2nd synthesis was to identify gaps in our knowledge of the Earth system, and contribute to a baseline for international research and policy in the area of GEC in the coming decades. A range of synthesis topics covering research under IGBP's core projects, joint projects and beyond were selected by IGBP's scientific committee with input from key stakeholders, including other relevant international programmes and the Intergovernmental Panel on Climate Change (IPCC). One of the topics selected for the IGBP synthesis was on Needs of Least Developed Countries (LDCs), from which a focus on the Asia Pacific LDCs was established through support from the Asia-Pacific Network for Global Change Research (APN).

Least Developed Countries (LDCs) form a group of 48 countries exposed to multiple stressors emanating from complex inter-linkages between local and global environmental and socio-economic challenges. LDCs are vulnerable because of inability to exploit economies of scale; limited diversification possibilities and human and institutional capacity; and high susceptibility to external shocks and natural hazards and disasters and environmental change. Out of the 48 LDCs, 33 are in Africa, 14 in Asia and one, Haiti, in South America (UNCTAD, 2013) (Appendix A) . In 2011 the population of LDCs constituted about 12% of the world and in 2014 the total population was estimated at 932.0 million (<http://data.worldbank.org/region/LDC>). Only four countries have graduated out of LDC category since 1964 when LDCs were first recognized by the United Nations Conference on Trade and Development, signaling the need for greater attention on addressing vulnerability of LDCs. It is against this background that during the consultative process for its second major international synthesis of key policy-relevant areas, IGBP resolved to incorporate a theme on "Global Environmental Change and Needs of LDCs". The purpose was to provide a coherent synthesis of GEC issues in LDCs that could help policy direction for e.g. under UNFCCC and guide development of strategies to address GEC within the LDCs and at the international level.

Although GEC programmes i.e. IGBP and regional networks such as APN generate vast information, policy makers in LDCs continue to rely on scanty and incomplete information, partly because available information lacks immediate local context for policy application. However, despite the vulnerability, LDCs have a great potential and wealth of indigenous knowledge that can be tapped to contribute towards addressing this vulnerability. This makes it pertinent that established solutions to problems of LDCs be adaptable to the local environment and easy to assimilate by the local population. As a result the goal of the synthesis was to build capacity in LDCs and facilitate integration of GEC science outputs generated by various international organizations with existing local information to support development agendas that address challenges of LDCs.

The overall administrative support of the synthesis was provided by the IGBP secretariat in Stockholm with some support from the IGBP Regional Office in Brazil while scientific coordination was under one of the IGBP Vice Chairs, Dr Opha Pauline Dube, based at the University of Botswana. The LDCs synthesis theme commenced in 2009 with the identification of focus areas through consultation within the IGBP Scientific community, its partners, National Committees and other international environmental research programmes. Extensive communication directed in particular to LDCs scientists and others working in these countries and including a call to submit indication of interest to participate and proposed area of focus led to the establishment of an International Steering Committee (ISC), the development of draft synthesis focus areas and selection of potential participants (Appendix B). The consultative process

established the need for a synthesis based on cross fertilization of scientific information produced at different scales i.e. from global to regional to local level, that addresses pertinent policy needs of LDCs, and identifies new areas that are of value to these countries for further development under the following sub-themes: hydro-meteorological hazards and disasters; human health and environment with particular reference to food security and water resources, and the role of indigenous knowledge systems in addressing global environmental change issues in LDCs. A planning workshop in Maputo, Mozambique in September 2010 gave selected participants the opportunity to i. deliberate on the broad focus areas of the synthesis and map out expected outputs, ii. deliberate on broad methodologies to accomplish the synthesis, iii. present areas of interest for feedback and iv. discuss how to maintain linkages among participating scientist and relevant international counterparts, engage decision makers and disseminate the synthesis outputs. The Planning workshop formed the bases for the development of a proposal on Global Environmental Change and Sustainable Development in the Asia-Pacific and SIDS LDCs that was subsequently funded by APN in 2011.

1.2. IGBP-APN Synthesis of the Asia-Pacific and SIDS LDCs

The IGBP-APN Asia Pacific LDCs and SIDS synthesis extends over countries that lie along zones of potent natural hazards in terms of geomorphological formations and position, variable climate resulting in cycles of drought, torrential rainfall, tropical cyclones, and others that have in recent years been enhanced by climate change and together with high population growth, poor planning and management of resources give rise to frequent disasters unleashing unprecedented human suffering and halting developments (Appendix C). The synthesis covered selected LDCs within this zone viz.: Bangladesh, Nepal, Bhutan, Afghanistan, Yemen, Myanmar, Cambodia, LAO PDR, Kiribati, Vanuatu and Solomon Islands, Samoa, Comoros and São Tomé. The emphasis of the synthesis was on capacity building in line with the APN goal on improving the scientific and technical capabilities of nations in the region. This was accomplished within the broad sub-themes of the overall IGBP theme on needs of LDCs but conducted under 5 sub-projects that are listed below together with the respective leading scientists in each case:

- i. Barriers to Reducing Climate-Enhanced Disaster Risk in Small Islands (*lead by Dr Natasha Kuruppu, Institute for Sustainable Futures University of Technology, Sydney, NSW 2007, Australia (in collaboration with Reenate Willie, Kiribati Ministry of Public Works and Utilities,)*)
- ii. Droughts in Environmental Changes and Sustainability of Asian LDCs (Prof Alimullah Miyan, IUBAT University, Bangladesh)
- iii. Challenges facing Bangladesh and Myanmar in Nurturing Marine Environment for Sustainable Development (Dr Shohidullah Miah, IUBAT University, Bangladesh)
- iv. Flood in the Context of Environmental Changes and Sustainability: Bangladesh and Nepal (Mr. Tanvir H. DeWan, IUBAT University, Bangladesh)
- v. Coastal Zone Management in Bangladesh (Dr Mohammed Aatur Rahman, IUBAT University, Bangladesh)

Prof Alimullah Miyan in IUBAT provided local coordination of the four sub-projects that were lead by Bangladesh based scientists.

2. Methodology

2.1. Introduction

The capacity to conduct a credible synthesis was achieved through a process of building on existing knowledge and skills of LDCs scientists and also through learning by doing. For example the Maputo planning workshop provided for a review and development of a framework for the assessment

methodologies through shared experience among participants. Capacity building was also established from interaction with a wide spectrum of fellow scientists, policy makers, stakeholders and communities during the process of gathering and communicating information on the synthesis. While those based in Bangladesh worked under the guidance of a more experienced scientist Prof Miyan. Further guidance was provided by the overall coordinator of the IGBP LDCs synthesis Dr Dube and the designated project leaders from the IGBP secretariat, Dr Jao Morais and Dr Karen Smyth. An international scientist in GEC, Dr Mannava Sivakumar who is also the Editor-in-Chief of the Weather and Climate Extreme Journal was engaged to assist in building skills among participants on peer reviewed publications, a process that included a write a paper workshop in Bangkok, Thailand in 2013.

Further, the project adopted an output oriented strategy punctuated by a planning workshop to develop the synthesis framework, followed by contribution to the APN science bulletin, A write a paper workshop and production of a special issue in the Weather and Climate Extreme Journal, development of policy briefs in English and translated to a local language and an information dissemination workshop in Dhaka, Bangladesh. This delivery driven strategy helped to focus data gathering and integration of evidence towards a common purpose, identify skills required and when to bring in new collaborators to fill identified gaps.

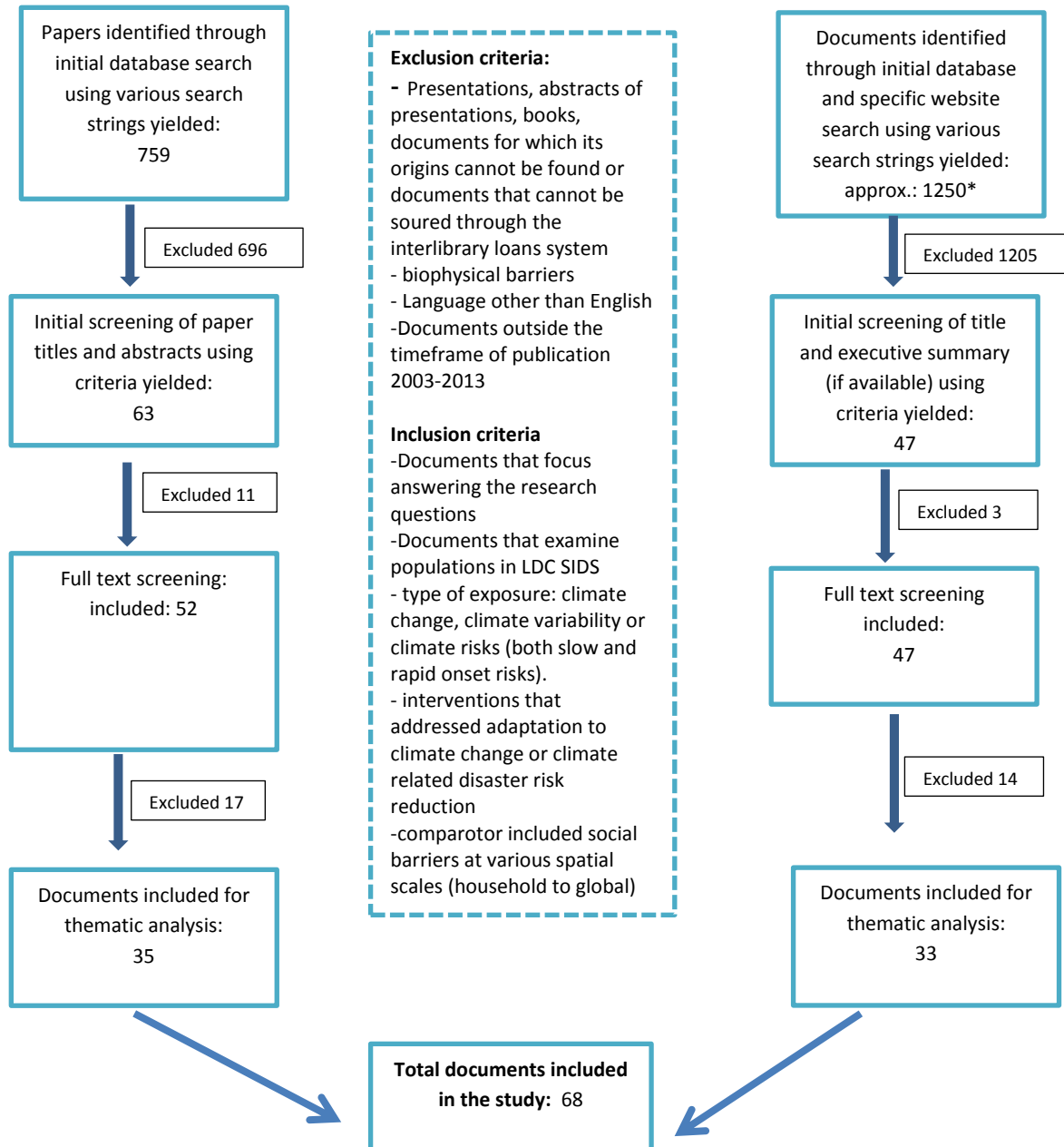
2.2. Synthesis methods

Overall the synthesis methods involved the following:

- An integrated literature review - assessed relevant scientific project findings, case studies, policy reviews and adaptation practices and integrated inter-disciplinary evidence, some produced across geographic and temporal scale and of a cross-sectorial nature i.e. integrating cross-cutting human activities such as water resources, agriculture, fisheries etc. to bring global and local perspectives over time.
- Synthesized and integrated information on biogeophysical, socio-economic, and management and practice established under different styles of knowledge creation, e.g. indigenous knowledge, conventional scientific knowledge and knowledge from practitioners e.g. management at national to local level. As a result authors have applied both within and beyond conventional science integration approaches.
- A systematic review methodology applied in particular for the SIDS study that was based purely on desktop review process. For this a set of inclusion and exclusion criteria for screening both peer-reviewed “academic” and non-peer reviewed “grey literature” publications to be included in the study was developed focusing particularly on various barriers to adaptation in LDCs SIDS (Figure 1).

Academic peer-reviewed papers

Grey Literature –not peer reviewed



*It was found that only documents appearing in the first two-three pages of the search results in Google or Google Scholar were relevant to the research study and thus downloaded where appropriate.

Figure 1. Systematic Literature Review Process Adopted for the LDCs SIDS synthesis

The synthesis was achieved through collection, collation, review and evaluation of the materials from the perspective of science and that of policy implication in the context of the country and the region.

Information was assembled through a desktop review of literature, direct linkages with science community, institutions, workshops, seminars and informal meetings with various stakeholders including policy makers and selective consultation of community leaders for traditional knowledge, some field observations and also through the peer review process. As a result published scientific findings, grey literature with some coming from popular media, plus ongoing practices and indigenous and traditional knowledge were used. The exception was the LDCs SIDS sub-section that applied a systematic review methodology mostly on peer reviewed publication using information gathered through student projects. All in all these processes facilitated cross-validation of the different across-scale sourced information used in the synthesis. The issue of validation of grey literature and traditional knowledge of LDCs has so far kept such knowledge outside the purview of policy framework. However, the validation of traditional knowledge is a broader issue that will be systematically addressed by the research community to evolve a consensual framework for such purposes.

The generated findings have been evaluated, reviewed and published for dissemination in the local, regional, and international policy forum. Production of a peer reviewed publication provided for international evaluation and quality assurance of findings in addition to presentations in regional and international workshops and conferences (Appendices 1, 2 and 4). The information dissemination workshop held in Bangladesh in September 2015 provided an in-depth evaluation by members of the LDCs. Awareness and practices have been built up through mass media and other communicative systems involving scientists, policy makers, academicians, researchers, stakeholders, NGOs and donors. Policy briefs have been developed in English and translated to one local language for Bangladesh where majority of the work was conducted (SADMC, IUBAT, 2015, Policy brief)

3. Results & Discussion

3.1. Introduction

Results and discussions are provided below per sub-project as follows:

- Barriers to Reducing Climate-Enhanced Disaster Risk in Small Islands.
- Droughts in Environmental Changes and Sustainability of Asian LDCs.
- Flood in the Context of Environmental Changes and Sustainability: Bangladesh and Nepal
- Challenges facing Bangladesh and Myanmar in Nurturing Marine Environment for Sustainable Development
- Coastal Zone Management in Bangladesh

3.1.1. Barriers to Reducing Climate-Enhanced Disaster Risk in Small Islands

I. Introduction

Small Island developing States (SIDS) share a set of common characteristics and challenges such as remoteness, rapidly expanding populations, excessive dependence on international trade, high transportation and communication costs, low availability of resources and susceptibility to natural disasters (Sem, 2007). SIDS classified as LDCs because of low income and other development indicators are particularly vulnerable to climatic risks due to their special characteristics such as physical size, proneness to natural disasters, the extreme openness of their economies and low adaptive capacity (Mimura et al., 2007). LDCs SIDS possess the lowest Human Development Index ratings of all countries in the world and reflect the lowest indicators of socioeconomic development. These include Kiribati, Tuvalu, Samoa, Solomon Islands, Timor-Leste, Vanuatu, Haiti, Guinea-Bissau, Comoros and São Tomé and Príncipe (Appendix A). Samoa is expected to graduate out of the LDC category in January 2014.

In response to the high vulnerability, many SIDS have initiated anticipatory adaptation actions through national adaptation programmes funded through the United Nations Framework Convention on Climate Change (UNFCCC). For example, the atoll nation of Kiribati was one of the first LDCs to initiate a development and climate change programme – the Kiribati Adaptation Programme (KAP), administered by the World Bank and funded through the UNFCCC. As early adaptors, SIDS provide a valuable context to study the initial bottlenecks and opportunities associated with formal adaptation planning and implementation. An increasing body of literature has focused on identifying various socio-economic barriers or constraints to adaptation. However, many of these studies have focused largely on developed country contexts with a paucity of literature on the most vulnerable low income countries such as LDC-SIDS (Biesbroek et al., 2013; Ford et al., 2011;). The goal of this synthesis was to expose and synthesize a key set of common barriers identified across LDC-SIDS through a systematic review methodology. Given that adaptation investments are currently underway in many SIDS, it is envisaged that the results of the synthesis will provide a useful baseline for measuring progress and success of adaptation efforts whilst highlighting policy areas that need further investments. Specifically the synthesis addressed the following objectives in relation to LDC-SIDS:

- To synthesize a set of key barriers/constraints to reducing climate risks through anticipatory adaptation and to identify their associated underlying causes.
- Identify the extent of the barriers that are addressed in formal National Adaptation Programmes of Action (NAPAs).

II. **Barriers to Adaptation**

Societies across the SIDS have developed various traditional strategies to deal with natural hazards and ensure resiliency to future stresses. For example, in Samoa when communities plant food crops, a patch is often reserved for use during the hurricane season. However, a synthesis of literature on barriers to adaptation found that the most common barrier reported related to governance followed in descending order by, technical, cognitive, cultural, financial and “other” barriers (Table 1). The “other” barrier related to the lack of focus amongst adaptation planning efforts on addressing the root causes driving social vulnerability. Details on these barriers can be found in the Special Issue of Weather and Extremes Journal (Dube and Sivakumar, 2015). Only selected barriers are presented here.

Governance as a Barrier: The most common governance barrier reported, related to the limited engagement between formal national adaptation efforts and communities or Local Government, was often created through weak linkages and poor coordination between the tiers of government. Consequently, this gave rise to poor communication between communities and government which often led to local or community needs being overlooked in adaptation efforts (World Bank, 2009).

Table 2 Barriers of adaptation among SIDS established from literature survey. Also included is the Frequency (‘n’) the barrier was discussed in the literature analyzed.

Financial (n=8)	Technical (n=15)	Cognitive (n=14)	Cultural (n=13)	Governance (n=24)	Other (n=11)
(n=4)* International adaptation funding for	(n=11) Paucity of baseline data related to climate and	(n=7) Vulnerability assessments and	(n=6) traditional knowledge, rituals and	(n=15) Limited engagement with communities	(n=11) Root causes of vulnerability are not being

Financial (n=8)	Technical (n=15)	Cognitive (n=14)	Cultural (n=13)	Governance (n=24)	Other (n=11)
LDCs; inadequate, unpredictable, complex to administer and inequitable.	natural resources as well as limited in-country capacity to generate and manage this data.	adaptation planning has given limited attention to community perceptions of climate risks and the influence of beliefs and values in shaping adaptation decisions.	cultural meanings play a key role in understanding how communities deal with environmental change; these are not often considered in formal adaptation planning efforts.	and Local Councils' implies that their needs for building self-sufficiency are often overlooked in national adaptation initiatives which tend to focus on top-down sectoral (e.g., water, health, agriculture) adaptation interventions.	addressed through current formal adaptation efforts. The need for actively navigated transformative adaptation through deep structural changes to address long standing issues of gender inequality, corruption, declining markets etc., has been overlooked.
(n=2) Lack of in-country capacity to access international adaptation funds and mobilise funds effectively particularly in rural areas or outer islands.	(n=4) Limited understanding on the impacts climate change on health systems and associated demand on the health workforce including facilities, drugs and skills.	(n=5) International discourses on climate refugees and climate migrants from LDC-SIDS threaten how SIDS perceive their future by silencing alternative identities, reasserting power imbalances and curtailing peoples' agency.	(n=4) Erosion of social cohesion and collective practices in communities has the potential to constrain adaptive capacity.	(n=4) Gaps in policy enabling environments at regional and national levels constrain adaptation planning and implementation within SIDS.	
(n=2) International		(n=2) Limited understanding	(n=3) Adaptation	(n=3) national policies and	

Financial (n=8)	Technical (n=15)	Cognitive (n=14)	Cultural (n=13)	Governance (n=24)	Other (n=11)
adaptation funding does little to address root causes of vulnerability through cross-sector initiatives and support programmes that allow communities to help themselves.		by the private sector on the risks of climate change on industry.	related education/info and other outputs are often not produced in local dialect(s) and thus impedes community ownership of adaptation efforts.	strategies related to climate change overlook issues of urbanisation, in-country migration and population growth whilst concurrently various sectoral policies addressing these issues fail to recognise climate change.	
				(n=2) LDC-SIDS often lack sufficient capacity to actively engage in climate diplomacy at the international level, and consequently have had limited influence in shaping negotiations at this level.	

Lack of community ownership was reported in cases where efforts had been made to engage communities in adaptation interventions, which had largely been externally driven; brokered by regional agencies with external donors on behalf of national governments. For example in Kiribati, national adaptation efforts funded through the UNFCCC failed to improve community wellbeing and daily realities of households in rural islands; most of the funding targeted urban areas through structural interventions such as constructing seawalls or spent on consultant fees (Gaillard, 2012; Kuruppu, 2009). Similarly in Vanuatu and Solomon Islands, weak linkages between rural and central governance meant that the adaptation needs of rural communities, comprising between 80% and 90% of the total population, were given limited attention (Wickham et al., 2009).

Sectoral driven interventions was found to be catalysed by donor preferences for adaptation funding in addressing top-down policy development targeting central government rather than empowering community level decision makers. Several studies reported that weakened local institutions and local leadership in rural areas had constrained the management of natural resources, which had in turn reduced the adaptive capacity of traditional governance structures (Bayliss-Smith et al., 2010; Albert et al., 2012). This signal the need for adaptation initiatives to focus on empowering local leaders (both young and old) through participatory processes. An additional barrier to adaptation was found to be related to the mismatch in policy enabling environments between regional (e.g., Pacific, Caribbean) and national levels. Dominant power structures at the regional and international levels have greater influence over this mismatch. For example, in Tuvalu and Kiribati, regional donors had contributed to weakening capacity and poor coordination between various government agencies within each country by focusing on their own agendas rather than those that reflected local or in-country realities (Urbano et al., 2010). SIDS need to focus on developing their own governance arrangement to strengthen coordination between agencies responsible for climate change adaptation and disaster management . Other governance related barriers were associated with firstly, the lack of integration of dynamic pressures such as climate risk induced migration, rapid urbanisation and population growth into national adaptation policies/strategies; and secondly, the limited capacity of government officials in LDC-SIDS to engage in climate diplomacy at the international level. In general there is a greater need for integrated adaptation programmes that address the broader drivers of vulnerability across sectors whilst concurrently mainstreaming adaptation into sectoral policies and strategies.

Cultural Barriers: Cultural barriers refer to the foundation of people's way of life, including the distinctive spiritual, material, intellectual and emotional features through which life is based. The main cultural barriers identified through the data relate to the limited consideration given in adaptation planning to the role traditional knowledge, rituals and cultural meanings play in communities when dealing with environmental change. For example, in Vanuatu and Samoa adaptive capacity of communities to disaster risks and climate change can be enhanced by building on existing traditional practices of openly sharing crop varieties and maintaining genetic material in reservoirs in farmers' fields (McGregor et al., 2011). Supporting such adaptation interventions can safeguard livelihoods as well as maintain food and nutritional security in each country. Several studies reported that the trend in declining traditional knowledge is a barrier to adaptive capacity of communities. In the Solomon Islands, erosion of traditional knowledge surrounding gardens and bushfoods precluded families passing this knowledge to the younger generations (Albert et al., 2012). Consequently, increase in pests and disease of food crops was reported, which had led to the reliance on imported, processed foods.

An additional cultural barrier related to the erosion of traditional social systems that support principles of intra-community solidarity, reciprocity and collective support. For example, in the Solomon Islands, processes driving this change were reported to include those that support individualism, for example, the monetization of inter-household interactions and principles of modernity and democracy. Community based adaptation initiatives which are being piloted through many of the NAPAs are likely to be undermined if they fail to recognize and alleviate those processes shaping vulnerability through the erosion of the collective nature of traditional social systems in SIDS. Further there is need for climate change risks to be communicated in local language and this can be a barrier where there is a diversity of languages as in Vanuatu and Solomon Islands.

Financial Barrier: Two of the three funding barriers related to the mechanism underpinning the allocation of international adaptation financing whilst the other concerned the lack of in-country

capacity to access and manage funds in rural areas. A common theme that ran through these barriers was the inequalities in power relations between LDC-SIDS and donor countries. Several studies asserted that international adaptation funding for LDC-SIDS was inadequate, unpredictable, complex to administer and inequitable. It was reported that LDC-SIDS such as Tuvalu found it difficult to compete with larger LDC countries such as Bangladesh in accessing Global Environmental Facility (GEF) funding to operationalize their NAPAs. Additionally, the application procedures are complex which precludes access to these funds; capacity building efforts are needed to address this persistent barrier. An additional barrier highlighted by the results included the in country capacity limitations associated with developing project proposals to attract and manage funding through the GEF.

Various factors contributed to this barrier which included the absence of context specific climate data that demonstrated impacts on various sectors or livelihoods, complicated nature of funding criteria, poor track record in project managing donor initiatives and in certain instances, the absence of a National Climate Change policy to guide sectoral level adaptation implementation. It appears that when proposals were successful, limited capacity existed within Local Government or other government agencies located in rural areas to administer the funds that were directed specifically at these areas. Lastly, the results highlight how adaptation funding at the international and regional levels is not directed towards reducing root causes of vulnerability and support programmes that allow communities to help themselves. The results suggest that through pilot projects, adaptation finance had generated dependence amongst communities for donor knowledge and funding whilst undermining adaptive capacity (Nunn, 2013).

Technical Barrier: The two most commonly identified technical barriers related to the limited data available on climate and other biophysical resources (e.g., biodiversity, water resources) as well as the capacity to generate and manage this data within SIDS. Certainly, the paucity of data is a notable fact for many SIDS. However, the persistence of this barrier undermines the extent to which government agencies in SIDS can make timely policy related adaptation decisions and advice communities and sectors on appropriate interventions (Ekström et al., 2013). Strategies suggested for overcoming such barriers included the development of guidelines that support informed monitoring and the development of national policies and programmes to address climate and water knowledge gaps that foster best practice management. In the Solomon Islands there seemed to be a considerable amount of historical climate data. However, it was scattered amongst agencies with limited formal processes for organising, archiving and sharing of the data.

Finally this synthesis failed to identify literature that demonstrated how mechanisms at the international scale or at the donor level are changing in response to overcoming some of the barriers identified above. Rightly, the focus must remain on the most vulnerable communities and sectors in SIDS. However, the failure to address barriers at the macro-policy level will ensure that many of the barriers identified through this study will remain unchallenged.

III. National Adaptation Programme of Actions (NAPAs)

The study reviewed five randomly selected National Adaptation Programme of Actions (NAPAs) to identify the extent to which adaptation barriers discussed may have been addressed in formal national adaptation efforts. The analysis revealed that the common barriers revolved around the vulnerability of the major natural resources on which livelihoods were dependent, such as on water, agriculture, biodiversity, fisheries and coastal zones. The NAPAs' recognised that the vulnerability of these natural resources is likely to be exacerbated by non-climatic drivers that constrain development pathways such

as rapid population growth and urbanisation. Analysis of the NAPAs confirmed that many of the proposed adaptation strategies focused mainly on these vulnerable resource sectors with limited discussion on their interrelations. All five NAPAs' highlighted a set of barriers to implementing NAPA actions. Many of these were related to the limited knowledge of climate change amongst communities and government agencies, institutional weaknesses (such as policy gaps), NAPA's being subsumed by other national adaptation initiatives (e.g., the Kiribati Adaptation Project) and limited financial resources and constraints to accessing these resources.

Despite the presence of community adaptation projects related to the key natural resource sectors, limited attention was directed at activities that specifically addressed the building of community cohesion, community leadership of youth or strengthening linkages between Local Government and communities. NAPA activities addressing root causes of vulnerability or undertaking system wide transformations were scarce. There was limited mention of activities to redress social inequalities such as gender, corruption, in-country migration, urban–rural disparities, land tenure, youth unemployment etc. The Samoan NAPA was the sole NAPA that acknowledged the influence of urbanisation on climate change impacts and subsequently incorporated climate adaptation activities into urban policies as well as implementing zoning and strategic management planning (GoS, 2005). Although all five NAPAs sampled identified vulnerable communities, there was an absence of activities demonstrating how inequalities in opportunity and outcome structures will be overcome for the most vulnerable.

IV. Conclusion

The results of this synthesis suggested the need for policy and practice interventions across all the LDC SIDS.

- First governance and their associated institutions play a critical role in shaping adaptation efforts in SIDS and thus the cross-scale linkages between various tiers of government (from regional to local) need strengthening to facilitate coordination, social learning and overcome power inequities if adaptation is to deliver cross-sectorial benefits. Moreover, regional and international adaptation policy frameworks need to acknowledge and reflect the local policy environments of SIDS. This calls for regional and international donors and implementing partners to reflect on their own policies and practices and question the fundamental changes required to occur internally if they are to meet the distinct cultural and institutional architecture present in SIDS. In particular there is a specific need to strengthen the linkages between national adaptation efforts and Local Government which offers niches for experimenting innovative community based adaptation. Moreover, limited knowledge exists in understanding the particular capacity needs of Local Government.
- Second, the significance of traditional knowledge and cultural practices in SIDS in shaping actors' perceptions of climate risks and their agency in undertaking adaptation must be considered in policies and strategies related to adaptation in all sectors, including the private sector which has been overlooked in many SIDS. Currently, the limited focus and investments in understanding and integrating traditional knowledge into adaptation efforts in SIDS is a concern. Inextricably linked to this is the limited investment or effort being made by donor communities such as the Least Developed Countries Fund and other funding bodies to firstly engage with local researchers or experts in SIDS rather than utilizing the skills of international fly-in and -out consultants to generate adaptation related knowledge to support donor investments.
- Third, strengthening of policies that explicitly promote the building of long-term technical expertise and scientific capacities in SIDS to generate the data and information needed to support adaptation decision making. This will require developed country scientists working alongside counterparts in SIDS, co-producing knowledge and transferring the necessary skills over timeframes that exceed

traditional short-term consultancies or Technical Assistance. Moreover, it will require funding that moves beyond capacity building workshops and instead provide sustained financing of both the soft and hard infrastructure required to support in-country data generation, management and dissemination, particularly in local languages. In addition south–south climate adaptation collaboration networks between SIDS themselves will be valuable.

3.1.2. Droughts in Environmental Changes and Sustainability of Asian LDCs

I. Background

Many authors and organizations have generated definitions and ascription of drought as a hazard. Among these, the most authentic one is by R. A. Warwick (1975) as ‘drought is a condition of moisture deficit sufficient to have an adverse effect on vegetation, animals, and man over a sizeable area’. The National Drought Mitigation Centre (NDMC), USA has classified droughts into three types namely meteorological, agricultural and hydrological. Regardless of the type, droughts have severe adverse consequences in economic, social, environmental and developmental terms. Globally the intensity of droughts is increasing due to shifting weather patterns and climate changes while the South Asian region have been found to be severely affected by droughts in this century.

According to the United Nations (UN), a Least Developed Country (LDC) is a country that exhibits lowest indicators of socioeconomic development with the lowest human developments index ratings of all countries in the world with respect to three criteria viz. poverty, human resource weakness and economic vulnerability. According to this categorization, there are 48 LDCs in the world which are spread over Asia and Africa (Appendix A).

Drought is one of the most complex natural phenomena, that is hard to quantify and manage, and has multiple severe social and economic impacts, especially in the Asian LDCs. The magnitude of these impacts is determined by the level of development, population density and structure, demands on water and other natural resources, government policies and institutional capacity, technology, and the political system (N. Eriyagama et al, 2009).

According to the Global Droughts Information System (GDIS 2013), short term global droughts remain constant across the world affecting 44 million people as of august 2013 with increased intensity in Asia. The University College of London reported that 258 million people were affected globally by exceptional droughts in last 36 months (fig. 1). Thus drought is a hazard affecting people in both developed and developing countries but with more severity in LDCs.

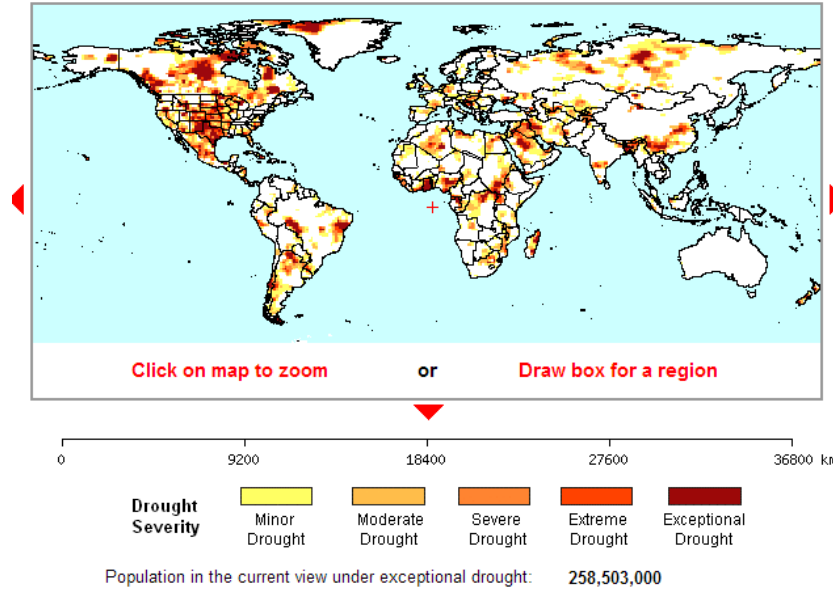


Figure-2: Population in the current view under exceptional drought. Source: University College of London

II. Drought Occurrence in Asian LDCs

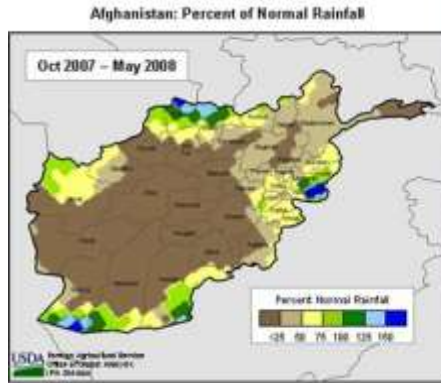
Mention has been made that there are 14 LDCs in the Asia Pacific Region (9 in Asia and 5 in the Pacific). Among them, Afghanistan, Bhutan, Bangladesh and Nepal belong to South Asia, Cambodia, East Timor, Myanmar and Laos PDR are in the Southeast Asia while Yemen is located in the Middle Eastern region. With the exception of Bhutan, all Asian LDCs experience frequent moderate to severe droughts of all types with adverse impacts on their people and economy.

a. Experience of South Asian LDCs

South Asian LDCs experience all types of droughts with high frequency, namely meteorological, agricultural, hydrological and socio-economic. The distribution of monsoon rainfall is found to vary inter-seasonally, inter-annually and inter-regionally causing droughts. Investigation indicates that crops and livelihood have been adversely affected by delay of monsoon by 20-30 days (Krishnamurthy et al, 2002). Drought period witnesses severe water scarcity resulting from insufficient precipitation and high evapotranspiration and over exploitation of water resources (Bhuiyan et al 2006).

Afghanistan witnessed the worst drought in its recorded history in 2011 involving 14 out of 34 provinces of the country affecting 2.6 million people (Huffington Post, 2011). Recent decades witnessed localized and wide ranging droughts as recurrent features in Afghanistan. Asian Development Bank reported that localized droughts have a periodicity of 3-5 years while droughts covering larger areas recur every 9-11 years. South and central areas of Afghanistan are most affected by drought between July and September. Since 1995, Afghanistan began experiencing unusual droughts which continue until heavy snow began falling in 2002-2003 winter season (OXFAM, 2011).

Extreme poor living condition prevails among the internally displaced population created by internal conflicts which has been accentuated by drought as depicted in figures 3 and 4.



Drought leaves this land barren in northern Afghanistan. Gutierrez noted that the frequency of droughts was steadily increasing and testing the resilience of entire communities.

Figs. 3 and 4 Afghanistan and Drought impacted fields

Bangladesh experiences drought from 6 to 7 months (November to May) every year when rainfall is normally low. Most areas of north-west, south-west and central zones had no rainfall during the 1998-1999 dry seasons. Data from 1949 to 1991 show that drought occurs in Bangladesh 24 times and severe droughts hit the country in 10 years and these droughts have typically affected about 47% of the area of the country and 53% of its population (Adnan, 1993). Bangladesh also experienced droughts of high magnitude in 9 years between 1973 and 1995 (Rahman 1995). Droughts of 1973, 1979 and 1994, 1995 (Figs 5, 6) were the worst in the recent history (Rahman 1995). Analysis of drought condition from the rainfall data of 1961-1990 confirm the historical record for the duration of the droughts (3-6 months with some exception) as can be seen in Table-3 (Rafiuddin et al 2001).



Figs. 5 and 6 Drought prone areas of Bangladesh and Drought affected Paddy

Table-3: Frequency of drought in Bangladesh for different short-month-length using Serial Peripheral Interface (SPI), calculated from the regional average (Choudhury et al, 2003):

Sub-regions	Month-1		Month-3		Month-6	
	Moderate drought	Severe droughts	Moderate drought	Severe droughts	Moderate drought	Severe droughts
Central	52	3	49	10	58	8
Northern	32	4	50	4	58	1
Eastern	35	1	45	3	39	2
Southwestern	44	2	49	4	62	3
Bangladesh	163	10	193	21	217	14

Bhutan experienced droughts in many parts of the country and the government of Bhutan has taken initiative to respond to the same through planning and working on water reservoirs and rain water harvest. Extreme variation in climate and weather patterns has been experienced in Bhutan. There is limited information available on prevalence of drought although individual municipalities or agencies have observed droughts on selected sites. The winter of 2005 and 2006 experienced unusually dried winter with no rain and snow (NDRMF, 2006).

Although Nepal experience infrequent droughts in 1972, 1977, 1982 and 1992 but frequency of dry spells increased from 2002. During 2002, 2004, 2005 and 2006 the country faced dry spells in both dry and wet monsoon seasons. Sometime the droughts have been followed by floods and heavy rainfall with adverse affects on agricultural production (WeAdapt, 2008). Nepal experienced worst drought in the winter of 2008-2009 (fig. 7, 8) and in these years, the country received less than 50% of average precipitation during the period November 2008- February 2009 as reported by the Department of Hydrology and Meteorology of the Government of Nepal (Joint Assessment Report 2009).



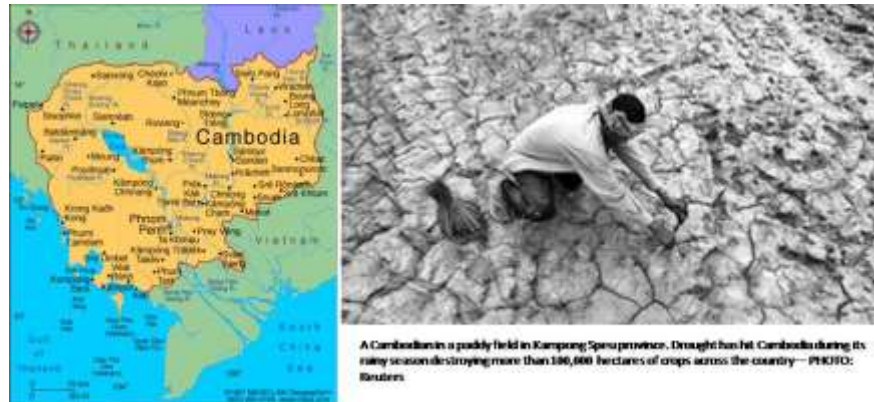
Figs. 7 and 8 Nepal and water crisis in Katmundu in March 2009

b. Experience of Southeast Asian LDCs

Southeast Asian LDCs are Cambodia, Myanmar and Laos PDR.

Cambodia experienced wide spread droughts throughout the country in 1986/87, 1994, 1997/98, 2004 and 2005 (Ministry of Environment, Cambodia 2002). Droughts devastated 9,990 ha of paddy field and affected 122,297 ha across Cambodia in 2012 as can be seen in figure 9 and 10 (phnompenhpost.com). According to Cambodia Disaster Statistics, historical droughts of 1994, 2002

and 2005 have seriously affected 5.0, 0.65 and 0.6 million people respectively with total economic loss of 138 million USD.



Figs. 9 and 10 Cambodia and Drought impacted paddy field

Droughts have been found to be most serious climatic hazards in 17 out of 20 provinces of Cambodia, the intensity and frequency of droughts have increased since 2000. The following graph (fig. 11) shows the pervasiveness of droughts to all provinces of Cambodia with 11 provinces as quite vulnerable, 2 provinces as vulnerable and 1 province as very vulnerable (NAPA 2006).

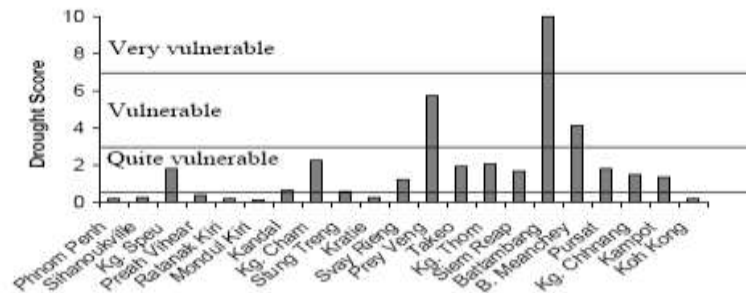


Fig. 11 Drought Vulnerability in the Cambodian Provinces [48]

Laos PDR experienced moderate to severe droughts in the years 1961, 1966, 1971, 1978, 1984, 1994, 1995, 1996 and 2009. Floods and droughts are considered the most frequent and damaging disasters in Laos (Figs. 12 and 13). Historical data recorded from 1966 to 2009 shows that Laos experiences an average of 1.5 severe flood and drought every year (GFDRR 2011).



Figs. 12 and 13 Laos and drought impacted paddy field

Southeast Asian countries are identified as climate change hotspots and about 105 million people are experiencing water stress in Greater Mekong. Mekong River Commission (MRC) reported that severe droughts caused rainfalls lower than average since September of 2013. MRC consisting of Vietnam, Cambodia, Laos PDR and Thailand is working together to solve this regional problem with the common approach to water sharing and to minimize drought effect in the region.

c. Experience of Middle Eastern LDC

Yemen is the only country belonging to LDC in the Middle East. The World Bank has described Yemen as "the single largest development challenge in the Middle East" — and this was before the recent weather-related problems. It is one of the poorest countries and about 22 million people have been struck by severe droughts and depleted water supplies in recent years (Kenyon 2008).



Figs. 14 and 15 Yemen and drought affected livestock

Yemen was seriously affected by severe droughts from 2007 to 2009 (Figs. 14 and 15) (www.irinnews.org) making it the looming catastrophe in the country. Yemenis receiving less than 200 cubic meters of water per person a year, well below the international water poverty line of 1,000 cubic meters clarifies the severity of droughts and water crisis of the country (www.theguardian.com). In Yemen, drought has caused displacement of thousands of people from mountainous villages in al-Mahwit Governorate in 2008 [IRIN 2008].

III. Impacts of Droughts

The Asian LDCs are facing serious socio-economic problems due to environmental changes caused by natural and climate change effects. Such environmental changes are also increasing the uncertainty relating to precipitation resulting in alternate patterns of floods and droughts. Most of these nations are densely populated and vulnerable to disasters but have very limited facilities and financial capacity to overcome the drought impacts.

Current extreme weather events are already taking their toll on these developing countries' economies, leading to loss of human and economic capital. Regions where climate change exacerbates climatic extremes especially droughts which have limited adaptive capacity will be further constrained in their development prospects due to additional loss of life, private assets, reduced productivity of important economic sectors, and destruction of infrastructure (OECD, 2003). Asian LDCs are most prone to this condition.

The effects of the drought are more devastating than the unpleasantness of temperature decreases in the agricultural and populated areas. With the persistent reduction of precipitation in these areas, lakes dry-up, river flow decreases and fresh water supply is squeezed, overwhelming available conservation options and depleting fresh water reserves.

The frequencies and intensities of droughts are increasing in the Asian LDCs having adverse affects on agriculture, biodiversity, water resources, uphill water-tables, ground-water recharging, hydroelectric power generation, drying up of streams and perennial springs especially in the dry season. Moreover, low or reduced precipitation/water flow has been increasing accumulation of dirty wastes and decreasing availability of fresh water especially in the urban industrial zones, and decreasing productivity with increasing pest and diseases affecting lives.

Economic consequences of drought are many such as loss of national economic growth, slowing down of economic development; damage to crop quality, less food production; increase in food prices; increased importation of food; insect infestation, plant disease, loss from dairy and livestock production; unavailability of water and feed for livestock leading to high livestock mortality rates; disruption of reproduction cycles; increased predation; range fires and wild-fires; damage to fish habitat, loss from reduced fishery production; income loss for farmers and others affected; unemployment; loss to recreational and tourism industry; loss of hydroelectric power; loss of navigability of rivers and canals, etc.

Environmental effects increase desertification; damage to animals; reduce and degrade fish and wildlife habitat. Lack of feed and drinking water, predation and diseases increase; wildlife are lost; increase stress to endangered species; damage plants; increase number and severity of fires, winds, soil erosion. Social effects include food shortages; loss of human life, heat, suicides, violence; mental and physical stress; water user conflicts; political conflicts; social unrest; public dissatisfaction with government regarding drought response; inequity in the distribution of drought relief; loss of cultural sites; reduce quality of life which leads to changes in lifestyle; increase poverty and cause migration (FAO, 2008). Competition for water in storage systems escalates during drought and conflicts between water users increase significantly.

Diverse biophysical conditions of Asian LDCs result in varied nature of climate change impacts. South Asian LDCs have some similar nature of drought effects and are densely populated, poor and most vulnerable (UN-OHRLS-2009, IPCC- 2001). Climate change is expected to have a significant impact on

agriculture in Asia. It may cause a decrease in the supply of water and soil moisture during the dry season, which could exacerbate stress on the available water supplies and increase the need for irrigation. Rice growing areas may also be affected, and the resultant decline in yield would have a significant effect on agricultural trade, economic growth and the development goals of certain Asian countries.

Droughts are recurrent features in Bangladesh and affect plant growth, loss of crop production, food shortages, and starvation. Drought affected households of the northern part of Bangladesh are severely affected; households belonging to the lower socio-economic group suffered the most (Paul, 1995). Due to non-availability of relevant data, the figures on the annual drought-related loss of crop production cannot be presented except for the 1982 drought. The total loss of rice production due to drought in 1982 was 52,896 metric tons (BBS, 1986) which is accounted for about 41% of the total damage caused by all types of environmental hazards. Brammer (1987) claimed that the 1978-79 drought reduced rice production by an estimated two million tons. It directly affected about 42% of the cultivated land and 44% of the population (Erickson et al, 1993).

In Bangladesh, drought caused severe stress to both crops and fruit trees particularly in areas where water cannot be pumped from the shallow aquifer due to drop-down or increased salinity. However, the increasing withdrawal of groundwater for both water supplies and agriculture, the severity of drought is not easily understood but water crisis is a great threat to Bangladesh (Rahman, 2011, Miyan 2012).

Bangladesh may face similar situation like Yemen as the cropping culture has mostly been changed and made irrigation dependent. Dry season agriculture has been the main source of increased food production over the past 20 years (BBS 1994). But this withdrawal of ground water is forcing water-table to go down and creating further crisis of water and increasing vulnerability of earthquake, especially in the cities where water-table is going down by more than one meter every year. Moreover, arsenic contaminated ground water is a serious problem in many of the northwestern districts of Bangladesh. More than 5 million people of Barind Tract are under a great threat due to severe impact of drought and arsenic contaminated ground water. Throughout Bangladesh, about 2 million small farmers and 2.4 million rural wage laborers are vulnerable to very severe drought. In the hills, more than 90% of the perennial streams have lost their flow in the dry monsoon resulting in serious water crisis for hill people which in turn resulted in break out of diarrhoea, dysentery and cholera etc. (Rahman, 2011).

High spatial and temporal climatic variability, extreme weather events, high population density, high incidence of poverty and social inequity, poor institutional capacity, inadequate financial resources, and poor infrastructure have made Bangladesh highly vulnerable to disaster (Shahid et al 2008, Ali 1996, Ahmed 2004). During the last 50 years, Bangladesh suffered from 20 extreme drought conditions. Despite the recurrent and devastating nature of droughts in Bangladesh, it has attracted far less scientific attention than floods or cyclones (Alexander 1995, Brammer 1987). However, losses from drought are likely to be more severe than from floods in Bangladesh (Shahid et al 2008). In comparison to flood, the impact of drought is of the same magnitude or even higher compared to the impact of floods and procedures set in place for flood management cannot be transferred directly for drought management. Drought assessment and alleviation is far more complex than flooding. Floods provide many positive services; drought none. Drought is a trans-boundary and basin-wide issue. These clarify the impacts of droughts and its adversity (Terink et al 2011).

In Bangladesh, a number of studies have been carried out on the impact of droughts on agriculture (fig 15) (Jabbar et al 1982, Karim et al 1990, Saleh et al 2000, Mazid et al 2005), food production (Ahmed et al 1989, Erickson et al 1993), land degradation (Rasheed 1998, Karim et al 2001), economy (Erickson et al 1993, World Bank Bangladesh 2000), and society (Erickson et al 1993, Paul, 1998). WARPO-EGIC (1996) prepared maps of winter and pre-monsoon drought prone areas of Bangladesh using the agro-ecological zones database and land resources inventory map. However, in Bangladesh drought is an ongoing silent disaster, as the people are mostly dependent upon groundwater for dry season agriculture, industrial usage, and for domestic and drinking water.

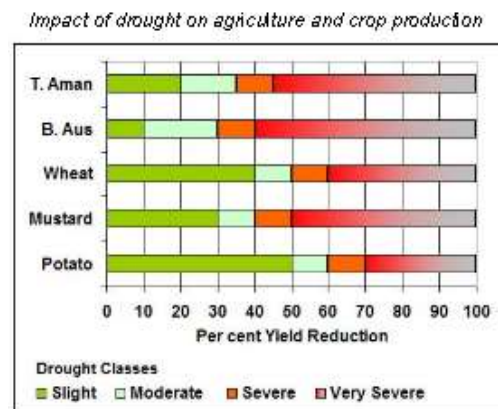


Fig. 16 Impact of drought on agriculture; Source: Climate Change Cell, Bangladesh 2006

Ahmed and Bernard (1989) and Hossain (1990), found that during the 1973-87 periods, crop losses to drought were almost as severe as the losses attributed to floods. About 2.18 million tons of rice was damaged due to drought in this period. Drought also severely affects the tea production of Bangladesh. In the 1960's and the 1970's and towards the end of 1990's the tea industry experienced prolonged drought which affected tea production. Prolonged drought for five months in 2006 affected the tea industry seriously (Hossain 1990). Due to drought the jute crop has also been affected by shortage of water. A large number of crops were damaged because the drought period corresponds with 1995 sowing period of Aus, Aman, and Boro rice, jute, and summer chilies; 1994 sowing period of winter crops: e.g., vegetables, potatoes, pulses, sesame (Til), Foxtail millet (Kaon), onion/garlic, chilies, and wheat); 1994 harvesting period of Aman rice; and 1995 harvesting period of Boro rice, and winter crops including wheat.

In Nepal, Tarai region, the low, flat land of the foothills of the Mahabharat Lekh range, the mid-mountain region with the valleys of Katmandu and Pokhara and the Himalaya most vulnerable to drought effects. Although Nepal is known as a water-rich country, holding second position after Brazil, the people of western Terai in the plain belt have been suffering from insufficient and unhygienic drinking water. Drought has reduced the water level in the well to the extent that residents are forced to drink poor quality water from a surface well sometimes one hour away from the village. In the dry monsoon (October – May), the western parts of the country remain dry affecting the agriculture and livelihoods. This makes life particularly difficult for those who have to collect the water. The existence of wide range of climatic conditions in Nepal is due to rapid changes in the altitude (Nayava, 1974). The average annual precipitation in Nepal is about 1600 mm, with large variations between eco-climatic zones. Domroes (1979) reported that there are east-west variations in mean annual as well as monthly precipitation at some stations in Nepal. The 2008-2009 winter season droughts impacted on crop loss and household food security, malnutrition, fresh water crisis, induced forest-fires e.g. fires detected

with Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data by the International Centre for Integrated Mountain Development (ICIMOD) revealed a large increase in the number of forest-fires in March 2009 compared to the same month last year—1500 fire locations compared to just 100 in March 2008 (WFP & FAO 2009).

Droughts cause considerable economic loss as well as social and environmental impacts which are increasingly affecting the human systems in Cambodia. It was found that, 20% loss in rice production due to droughts in five years (1998-2002) which is projected to increase in the future (Ministry of Environment, Cambodia 2002, NAPA 2006).



Fig. 17 Migration of and Impact on Fish Species due to Droughts



Fig. 18 Droughts Leading to Harvesting of Paddy as Fodder

In Cambodia, the last major drought occurred in 2002, affecting eight provinces and over two million people (Figs. 17 and 18). According to a study by World Food Programme (WFP) and the National Committee for Disaster Management (NCDM), around 270 communes out of total 1,621 communes in Cambodia are prone to drought and around 260 communes are prone to flood. Provinces such as Prey Veng may even be hit by both floods and drought in the same year. However, only about 40,000 out of the 310,000 hectares of cultivated land in Prey Veng are estimated to have irrigation systems, meaning that over 80 percent of cultivation depends completely on seasonal rainfall and weather. Therefore, most farming households bear the full brunt of floods, droughts, and pest infestations.

In Mekong, there is a sharp decline in supply of drinking water and irrigation. Drought has an adverse impact on agriculture, food security, access to clean water, energy production, river transport, tourism and recreation, forest and wild fires, human health and economic development of people facing poverty. Rice farmers are forced to plant crops that require less water and refrained from planting a second rice crop. Subsistence farmers have to seek new off - farm job and change their way of life because crops (rice, coffee, sugar etc.) were damaged and stressed (Polpanich et al 2010). Drought of 2010 in the Mekong Basin hampers Southeast Asian economy both agriculture, tourism and other industries relying on the river by drying up (The Bangkok Post 2010). The Inter-governmental Panel on Climate Change (IPCC) concluded in their Assessment Report that low rainfall and higher temperatures will intensify drought in the Mekong Region substantially (Terink et al 2011).

In Laos, there is serious concern that widespread deforestation could lead to a significant decline in rainfall and trigger a positive-feedback process of increasing desiccation for neighboring forest cover; reducing its moisture stocks and its vegetation would then further the desiccation effect for the region. Subsequently there is a decline in rainfall, subjecting the area to drought. If rains stop falling, within a few years the area can become arid with the strong tropical sun baking down on the scrub-land and become more prone to devastating forest-fire (Butler 2012). According to WFP, in 2010 (WFP 2010)

many parts of the country reported drought conditions which delayed the planting of rice. These natural disasters represent shocks that can lead to a rapid deterioration in the nutrition situation.

Because of economic, geographic, climatic, cultural, and political challenges, Lao PDR continues to suffer from high rates of under-nutrition. It faces three particularly serious problems: wasting, stunting, and micronutrient deficiencies. In June 2010, the province of Attapeu had an overall acute malnutrition rate of 18.9%, which exceeded the emergency threshold of 15%. In Sarvavan and Savanakhett provinces, the levels were above the emergency alert level of 10%. At these rates, children were at serious risk of dying. Because the high levels of anemia and vitamin A deficiency continue to pose a serious public health problem, reducing micronutrient deficiencies is the third priority of WFP in Lao PDR (WFP 2010).

The majority of Bhutan's population depends on subsistence farming for which timely precipitation is necessary. Drought and erratic rainfall make the Bhutanese communities especially the rural population highly vulnerable to impacts of extreme weather patterns. Forest fires are a common threat. Increase in temperature and drought incidences also increase incidences of forest fire. Climate scenarios prepared using Providing Regional Climates for Impacts Studies (PRECIS) model under the Second National Communication from Bhutan to UNFCCC indicate that winters in Bhutan will be drier and warmer in the future and this finding is consistent with other regional and global models (NAPA 2012).

In Dagana dzongkhag, there was no rainfall for four months in 2012 which seriously affected vegetables and all other cereal crops. Consequent to the prolonged dry spell, crops are scalded, some to the extent of no rejuvenation. The rain become scarce in most part of Bhutan and farmers suffered severe dry spells (Lhakapa 2012) and farmers started converting paddy fields into dry farming owing to acute shortage of rain water (Palden, 2011).

Inadequate rains and snowfall during 2008 to 2010 in parts of Afghanistan caused significant failure of the rain-fed crops in six provinces: Herat, Jawzjan, Balkh, Badghis, Faryab and Sar-e-Pul (UPI 2011). These led to severe drought affecting northern parts of Afghanistan with consequences of dried pasture lands, reduced water sources and death of thousands of animals. In Samangan, about 1,400,000 animals have been sold at low prices, while about 30% perished due to drought (IRIN-2008). Nearly three million people have been facing severe food shortages as a result of drought in 14 of Afghanistan's 34 provinces. Eighty percent of the non-irrigated wheat crop has been lost (RIN 2011).

In Afghanistan, the impacts of droughts are multidisciplinary starting from agriculture, herding, drying up of pasture, acute water crisis, food security and malnutrition and domestic water shortage resulting in epidemics (OCHA 2011). It has been further reported that drought caused serious shortfall of foods especially the rain-fed wheat up to 80% shortfall in the north and northwest; along with a combination of health, nutrition, water and sanitation activities, to prevent malnutrition and outbreaks of communicable diseases The situation affected the most vulnerable populations and their access to food and water, negatively impacting on health and nutrition status of the involved communities (UPI 2011).

Yemen is one of the oldest irrigation civilizations in the world. For millennia, farmers have practiced sustainable agriculture using available water and land. Through a myriad of mountain terraces, elaborate water harvesting techniques and community-managed flood and spring irrigation systems, the country has been able to support a relatively large population. Yemen is now facing a water crisis unprecedented in its history. Presently, Yemen is one of the world's ten most water-scarce countries. Withdrawal of ground water has caused drying up of the aquifers; threatening agriculture and leaving

major cities without adequate safe drinking water. Sana could be the first capital city in the world to run dry. Even today, many wells have to be drilled to depths of 2,600 to 3,900 feet, extremely deep by world standards.

In Yemen, low rainfall and subsequent drought contribute to and speed up overgrazing in the Highlands. However, in the coastal plains where rainfall normally does not exceed 150 mm, the annual vegetation mainly comprises dwarf shrubs, herbs and annual grasses; hence such pasture cannot support large numbers of grazing animals. But if grazing continues too long, then the pasture is more overgrazed as a result of high stocking rate and drought (Alabsi 2001).

Extreme weather conditions and environmental changes are confusing farmers and threatening livelihoods, further aggravating Yemen's already fragile food security. Due to lack of research, there are no numbers that accurately describe how drought is affecting Yemenis. However, one thing is clear; Yemeni farmers' attitudes towards planting have changed. Yemen is getting hotter by the year towards climate extremes. According to the National Council for Climate, there has been an increase in average temperatures in the capital Sana'a over the last 20 years, though they do not have an exact figure due to a lack of research (MERIP 2013). Agriculture takes the lion's share of Yemen's water resources, sucking up almost 90 percent. Until the early 1970s, traditional practices ensured a balance between supply and demand. Then, the introduction of deep tube wells led to a drastic expansion of land under cultivation. In the period from 1970 to 2004, the irrigated area increased tenfold, from 37,000 to 407,000 ha, 40% of which was supplied by deep groundwater aquifers. Thousands of Yemenis working abroad often invest their remittances in irrigation. Other incentives to expand farmland came in the form of agricultural and fuel subsidies. Farmers began growing less of the local, drought-resistant varieties of wheat and more water-intensive cash crops such as citrus and bananas.

The emerging cash economy also led to a dramatic increase in the cultivation of qat -- the mild stimulant whose leaves are chewed in Yemen. It is estimated that qat production now accounts for 37% of all water used in irrigation. In the water-stressed highland basins of Sana, Sa'da, 'Amran and Dhammar, qat fields now occupy half of the total irrigated area. Groundwater levels in these highlands have fallen so precipitously that only the lucrative returns from qat justify the cost of operating and maintaining a well.

Qat is grown as well in the Sanaa basin, where the capital is located and 10 percent of the Yemeni population lives. A total of 13,500 wells have been inventoried in the basin. The vast majority of them serve farmers, but the water is disappearing. In the mid-1990s, extraction in the catchment area exceeded recharge from rainfall by over 400 percent. Available data give the Sanaa aquifer two decades of life, after which irrigated agriculture in the basin will end.

Yemen is under "serious water stress" according to a report by the UN Economic and Social Commission for Western Asia (UN-ESCWA). Climate change during the last few years and especially in 2009 is a real concern for Yemen, particularly if the frequency of precipitation events continues to diminish, putting agriculture in peril and potentially leading to a catastrophic drought as the rainfall patterns are changing. The rainy season in Yemen is usually from March to May and July to September, but rains are now starting in August.

Much like the rest of the region, the climate change impacts facing Yemen are drought and desertification on the one hand and torrential downpours on the other, rains that are useless because they are not harvested or channeled in any way. The concept of Integrated Water Resources

Management (IWRM) is still new to Yemen and needs to be applied by the water sector in order to strike a balance between water replenishment and usage.

Geographical location in an arid area makes it especially difficult for Yemen. It rains four months in a year, the rest of the year is dry. The population increase, especially in the mountainous area where up to 90 percent of the population density distribution is located, further aggravates the water crisis. Most of the population is also concentrated in the major cities. This puts pressure on ground water and an annual drop of four to six meters in most of the groundwater resources (The Yemen Times 2009).

IV. Coping with Droughts

LDCs evolve their own ways to cope with the impacts of climate induced droughts. The food consumption in the community decreases particularly among the small farmers and landless laborers due to decreased food production, abnormal increases in food grain prices, and non-availability of jobs. At this stage, drought victims often are compelled to buy food by selling their lands, household goods, and livestock at distressed prices (Reardon et al 1988). People start to consume wild plants, tubers, and leaves not normally eaten (Jallow 1995). This is the 'early warning' for famine. At this stage, the drought affected people need additional food from different sources for consumption as relief or at subsidized prices. The country government and NGOs should take responsibility for averting famine condition through food and employment provisions. Failing such responses famine becomes unavoidable.

To cope with effects of droughts, people adapt various strategies. At the household level, people adapt agricultural and non-agricultural adjustment to cope with the effects of drought hazard. Agricultural adjustment involves re-sowing of crops in order to compensate for the reduction in the crop area, and others, such as application of irrigation water, to increase crop yield (Brammer 1987). During the drought period food prices increased abnormally requiring more cash for survival and people adapt non-agricultural measures for this purpose. The need for cash is further aggravated due to remarkable decrease in demand for agricultural wage laborer. As a result, people either sell and/or mortgage their land and livestock, and sell their belongings to acquire additional cash.

All members of the affected community are not equally vulnerable to drought. At the community level, friends, neighbors, relatives, and affluent members of the community may help the drought victims by providing cash, loans, food, and clothes (Paul 1995). Beyond the community level, the national government as well as friends and relatives of the drought victims who live outside the victims' community can play key roles by providing financial and other support to overcome the hardships of the drought victims as well as to halt the occurrence of famine. Distribution of free food, clothes, medicine, and other relief goods is the appropriate public response to drought hazard. The government can also minimize hardships by creating employment opportunities for the drought victims and providing financial assistance.

NGOs usually extend their support to the drought victims to cope with losses. Indeed, the impact of the drought can be reduced significantly if all parties respond to the hazard adequately in appropriate time. The government's interventions are particularly needed to avert famine and minimize the hardship of the drought victims. People used to follow some special techniques like fish, meat and fruit preservation; surface and rain water storage in large reservoirs like Ramsagar (Fig. 19) and Sagar Dighi in Bangladesh, which are the man made practices to cope up with the adverse condition.



Fig. 19 Ramsagar Dinajpur: A manmade Pond 1,079 m X 1,926 m, excavated in 1750s, funded by Raja Ram Nath, using about 1.5 million Laborers in northern drought prone Bangladesh (<http://en.wikipedia.org/wiki/Ramsagar>)

Researches on drought resistant crops are in progress; however, traditionally people used to adjust their crops with the climate. But with the increasing hybridization for HYV crops to achieve high yield and to increase cropping intensity the demand for water has increased manifold. Moreover, crops are losing their immunity and become more prone to disease and climate adversity. Some LDCs including Bangladesh have started growing food tree crops which are much less susceptible to drought effects and thus reducing food and nutrient crises. During tree crop production, trees get water and nutrients from deep soil and also mitigate droughts by transpiration.

Traditional climatic manipulation techniques, use of sun, shade and partial shade loving crops of diverse species and their management techniques are the options for mitigation of adverse impacts of climate change leading to droughts.

Sustainable landscape management involving traditional flood-plain management is necessary to find a solution for the recharging of ground water to solve acute water crisis (Fig 20 and 21). Afforestation and tree plantation is an important measure to restore the hydrological cycle and keeping humid atmosphere and the government has taken massive plantation program on the hills, along the roads and highways, riverbanks and also in the coastal zone under public private partnership (PPP) viz. social forestry; NGOs. Private sector initiatives are also important on extension of forestry.

For the adaptation measures including traditional coping behavior, awareness and capacity building and preparation of NAPA, Standing Orders for Disasters (SOD) has been prepared by many LDCs. Changing habits, lifestyle and cropping patterns, and creation of Climate Resilience Fund: Bangladesh Climate Change Resilience Fund (BCCRF) has approved \$ 153 million projects to fight adverse impacts of climate change that may lead to subsiding of droughts. Moreover, emphasis has been placed on dissemination of information on enhanced disaster and health risks due to climate change. Though fallacy in adapting with droughts is prevalent among some 24% of the people of around 17% households have reduced water consumption by limiting bathing in a week in Cambodia (NAPA 2006). Few countries e.g. Laos and Cambodia have adopted drought monitoring, drought risk mapping and quantification of drought risks (Terink et al, 2011). The SAARC Meteorological Research Centre (SMRC) has initiated a drought research project for Bangladesh and Nepal considering the growing uncertainty

of monsoon precipitation; to calibrate regional climate model baseline data sets with observed values. Such study could be extended to other countries and regions.



Fig 20 Indigenous traditional mechanism for transferring/ preserving/harvesting water from mud-hole during droughts



Fig. 21 Indigenous traditional mechanism for harvesting mountain water through tree-shell during droughts

The government of Nepal formulated the National Strategy for Disaster Risk Management (NSDRM) in 2008 to enhance capacity and resilience to respond to disaster risks. This directly contributes to the national commitment on Hyogo Framework of Action and to the work of the Nepal Risk Reduction Consortium (NRRRC). Effective roles of the ministries have been emphasized in devising and incorporation of an integrated and comprehensive disaster risk management program into the annual development plans. The UNICEF and government of Nepal have budgeted US\$5.225 million for disaster risk reduction as well as emergency preparedness in the hazard prone areas for the period of 2013-2017 (UNICEF Report 2013) may lead to improved access to supports for members of the drought affected communities of the country.

Yemen has drought mitigation plan and drought management actions on project basis. This might be incorporated into the biodiversity and climate change strategy of the country. This country would need assistance in drought projection, development of national drought strategy, action plan, and adoption of standard approach, monitoring and warning system, preparedness and mitigation action, emergency response and recovery measures as well as impact assessment (DESA and ESCWA Report 2013). The Integrated Water Resources Management (IWRM) is new to Yemen but the country needs to strike a balance between water replenishment and usage.

V. Drought Vulnerability Reduction

Adjustment of cropping with changing weather conditions is practiced by many farmers and this might be replicated. Some drought resistant crop varieties have been developed in Bangladesh viz BRR1 dhan56 and BRR1 dhan57 to reduce vulnerability of droughts and these are giving results and might be replicated. In case of no alternatives, the replacement of field crops with fruit trees may have to be resorted but it will have to be ensured that cereal crops are replaced with only fruit trees so production of food items are ensured.

In many places, permaculture, mulching, and traditional harrowing followed by powdering the soil are being practiced to protect evaporation to minimize impact of droughts.

Cropping with pumping ground water helps avert immediate effects of droughts but the same has long term consequences like lowering of water level. Therefore, pumping ground water might be promoted only in case of emergency. If so is promoted, this should be done with integrated culture with paddy,

duck, oyster, crabs and turtles so this gives multiple outcomes as well as avert the consequences of less production of fish due to drying up of the ponds and lakes. This practice might be combined with water efficient cropping. Adoption of this integrated cultivation would lead to crop diversification and high yield to meet required demands for food.

Development and use of technologies for bio-fortification of cereal grain crop may be promoted in the overly populated drought prone areas to meet the nutritional needs of the people during crop failure due to drought condition. Genetically added micronutrients like zinc, boron and manganese etc are found to be drought resistant and induce other nutrients to uptake.

The consequences like diseases and malnutrition among children might be minimized through making juicy foods available during the scarcity of fresh water due to drought condition.

Creation and utilization of deep water reservoirs in the drought prone regions may significantly reduce the vulnerability to drought conditions. In such cases, a balance between needs for deep water reservoirs and increased population pressure combined with needs for increased cropping will have to be drawn.

Development and dissemination of survival techniques among drought prone communities may avert helplessness and mass suicide emerging from drought conditions.

Education, training and research in the field of remote sensing/geographical information system (RS/GIS) are needed to integrate drought monitoring study, as well as information sharing. Development and use of drought forecasting and early warning systems might be promoted in the drought prone areas. The indexes already developed like Palmer Drought Severity Index (PDSI), the Crop Moisture Index (CMI), Serial Peripheral Interface (SPI), Surface Water Supply Index (SWSI) and Dry Index etc may be shared with the individuals and organization working to reduce vulnerability of drought in the drought prone regions.

Capacity building activities in the drought prone areas in the form of developing scientists to carry out meteorological and hydrological research on forecasting and warning could have the potential of developing better forecasting techniques and early warning for adaptation to drought conditions.

Continuous research, education and training programs could increase drought awareness and relevant knowledge for management of drought in LDCs. Development and sharing of simple toolkits or methods could assist the community or local government to monitor drought severity and initiate both mitigation and adaptation measures.

Some institutes and NGOs are providing training to the youth and women bodies for sustainable uses of water resources, recycling and reuse of grey water, traditional rain water harvesting and purification.

Technical assistance and consulting services is a need for advanced drought monitoring and assessment study and even move further to establish early warning system for drought. LDCs have recognized that there is a limited knowledge and understanding of drought disasters, impact assessment, early warning system with great effort in real time monitoring, ground data and tool for validation of drought monitoring using RS/GIS are unavailable and inaccurate like soil moisture content, precipitation.

Knowledge based area development (KBAD – www.iubat.edu/kbad), a unique concept for human resource development for capacity building of youth with skills to diversify occupation as practiced by one institution in Bangladesh, specially for famine (monga) affected areas has the potential to reduce drought related vulnerability in the Asian LDCs.

The Cambodia's Initial National Communication under the UN Framework Convention on Climate Change of the Ministry of Environment, Cambodia offers some proactive ways forward for reducing drought vulnerability viz. (i) development of new high yielding drought resistant varieties, (ii) improvement of crop management and cultural practices, (iii) development of capacity for better adaptation like development of early warning system, development of maps showing rice growing areas prone to drought (iv) development of irrigation facilities for low lying areas, (v) increasing planting index in suitable areas and (vi) diversification of food. Cambodia has also incorporated climate change awareness education into the secondary education curriculum, established forum and trust to reduce vulnerability. Other LDCs could draw on the Cambodian experience.

Wide ranging gaps in research and knowledge generation on drought hazard prevalent in the Asian LDCs has made initiative of country level study an imperative for development of a comprehensive conceptual framework for study, mitigation and adaptation to combat consequences of all types of droughts.

I. A. Modeling Climate Change Induced Extreme Events including Drought

Vulnerability of Bangladesh due to extreme climatic events has been analyzed by various models and results of the models showed significant upward trends due to climate change. Adequate information exists for analysis of various events such as temperature increment, sea level rise, flood, drought and cyclone at the global scale but the information required for modeling at the different regions of Bangladesh is very scanty. This work synthesized various climatic models on Bangladesh to predict the future possible adversity of the extreme climatic events.

1. Drought

Drought frequency and intensity will increase in the coming years having negative impact during the post-monsoon to pre-monsoon cycle, as rainfall diminishes while temperature increases. Bangladesh witnessed driest monsoon in 2010 since 1994 (Rajeevan et al 2011). Production of wheat, rice variety of HYV Aus and Boro might no longer be economically suitable under climate change induced drought as predicted by the models in 25 to 30 years' time span.

2. Flood

Flooding and the inundation risk exposure in the Ganges-Brahmaputra-Meghna basin up to 2050 showed that both increase in inundation area and depth due to climate change will be up to 6% (IWM, 2009). This flood model was developed by Bangladesh Water Development Board (BWDB). Flooding in Bangladesh in 2007 affected 13.7 million people with 1110 deaths (Rajeevan et al 2011). Prediction on climate change and flooding in Bangladesh is shown in Table-4 (Dasgupta et al 2010). In terms of flood risk exposure zones, areas inundated to depths greater than 0.9 m increased from 34% of total area under the baseline scenario to 40% under the climate-change scenario (Fig. 22) (IWM 2009).

Table 4: Climate change and flooding in Bangladesh

Additional Inundation Depth due to climate change (cm)	Area (sq km)	Share of total area (%)
No Change	70,249	52.6%
1 – 5 cm	56,102	42.0%
5 – 10 cm	5,841	4.4%
10 – 15 cm	786	0.6%
More than 15 cm	544	0.4%
Total	133,522	100.0%

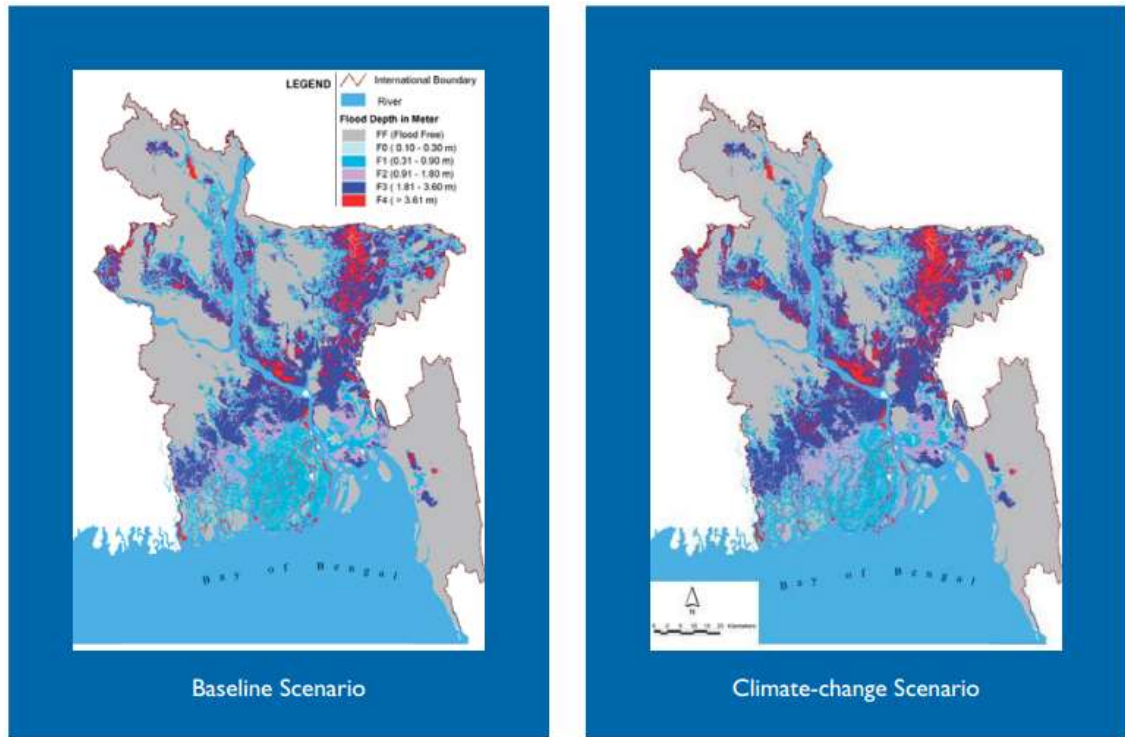


Fig 22: Flood risk exposure map of Bangladesh

3. Sea Level Rise [SLR]

There will be increasing risk of coastal salinity and fresh drinking water by the Sea Level Rise (SLR) that will contribute to upward trends in extreme coastal high water levels in the future predicted by modeling (very likely). This is threatening for Bangladesh as many regions of the southern part of the country is just one meter above sea level on an average (Fig 23) (Climate Change Cell, 2006).

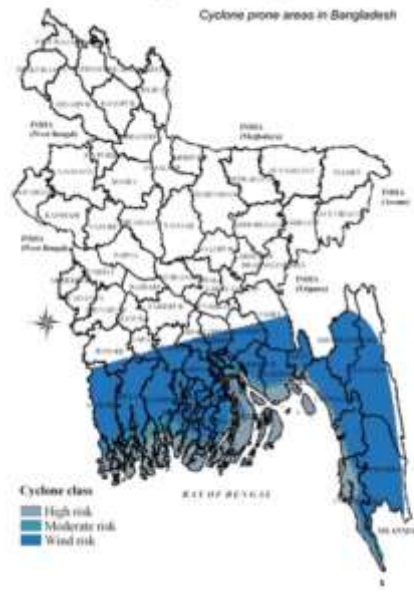


Fig 23: Cyclone prone areas of Bangladesh in climate change condition [1]

4. Cyclone

Bangladesh is a global hotspot for tropical cyclones (UNDP, 2004). To determine potential future inundation zones by 2050 under the climate change scenario, the storm surge model was run. Under the climate change scenario, the vulnerable area would be 55% greater than the baseline scenario (IWM 2009). This will bring loss of lives, property and an increase in the cost of adaptation in the cyclone prone zones of Bangladesh.

5. Challenges of Climate Change Modeling in Bangladesh

Climate modeling involving different agro-ecological zones of Bangladesh is necessary to generate region specific adaptation plan for agriculture and economic policy. This is presently at infancy due to lack of expertise, technology and scientific orientation. Capacity building for climate change research could bring rich dividend.

I. B. Cereal Production and Drought Risk Management

Rice, wheat and maize are the top three cereal crops that are consumed throughout the world. Water and nutrition are two major components of environmental variations and together provide limitations to successful crop production. Mineral nutrients are essential for plant growth and development through their fundamental roles in metabolism, while drought is prominent among the most important ecological factors that impact crop growth and productivity. Many physiological processes in plants are impaired by drought stress, including photosynthesis, enzyme activity, membrane stability, pollen viability and ultimately growth. Drought is a major cause of yield and quality loss in cereal crops.

Drought has been found to be one of the major environmental factors which limits both quality and quantity of rice, maize and wheat production in Asian LDCs. While the interactions of drought stress and these other stresses have generally received a reasonable amount of discussion in the literature, the interaction of drought stress and nutritional stress seems to have received little attention. Asian LDCs soils are deficient in many macro-micronutrients essential to plant growth and zinc and boron and manganese is no exception although these

nutrients are involved in a wide range of physiological process and several of these are also associated with tolerance to drought stress. Drought and low nutritional status of soil often occur in combination throughout the world's cropping areas.

Experiments were carried out to find out the effects of drought stress and NPK along with zinc, boron and manganese nutrition on the growth, grain yield and grain quality of cereal crops. It was demonstrated that foliar application of Zn, B, and Mn alone can increase grain yield of cereals under drought stress. Further field experiments are suggested to determine what the effect is when Zn, B, and Mn are combined and applied in a 'cocktail' as two-to-three foliar applications shortly before flowering. It is also desirable to work with some other micro-nutrients to find better solution to mitigating drought effects in different drought prone regions. This work will be highly relevant to farmers and extension workers to increase efficiency in crop production with less water and under drought stress.

VI. Drought Related Policy Priorities

Deep water reservoir: Traditional surface deep-water reservoirs have been found to have positive impact on mitigation of drought. However, such water reservoirs are under considerable threat due to increased population pressure as well as cropping. Therefore, formulation of legal framework and administrative measures by the LDC governments can contribute to drought mitigation.

Adaptation to Draught: Farmers resort to different measures for adaptation although hopeless situation sometime lead to extreme consequences like the mass suicide as happened in parts of India this year.

Crop Diversification: Farmers adapt less water demanding crops and also switch to dry season cropping with irrigation. In extreme cases, field crops are replaced by tree crops. Promoting information on water efficient crops and irrigation facilities would lead to extensive practice of these.

Drought Resistant Crop Varieties: Bangladesh has developed two varieties of rice namely BRRI dhan-56 and 57 but the same is going through field experiments. Therefore, more focus is required by scientific community and developing country governments on drought resistant varieties of produce and efficient use of water resources.

Indigenous Culture: Permaculture, mulching, and traditional harrowing followed by powdering the soil to protect evaporation etc. are being practiced in some areas but on a limited scale. Such practices deserve to be documented for efficiency measures and information sharing for wider practice.

Biofortified Cereals for Drought Management: Asian LDCs, especially those densely populated like Bangladesh can harness increased bio-fortified cereal grain crop to manage drought and nourish its huge population. Genetically added micronutrients like zinc, boron and manganese etc. are found to be drought resistant and induce other nutrients to uptake. In-depth research on locally available genotypes, their behavior and interaction with climatic conditions is required for this. However, the limited financial and technical capabilities of LDCs call for support from international agencies and research laboratories of developed countries to achieve this goal.

Forecasting for Early Warning: Historical records of managing droughts tell us that early awareness can reduce its impacts. Drought forecasting and early warning are still at infancy. South Asian and lower Mekong River countries practice some early assessment in the form of indexes such as Palmer Drought Severity Index (PDSI), the Crop Moisture Index (CMI), Serial Peripheral Interface (SPI), Surface Water Supply Index (SWSI) and Dry Index etc. More resource investment by governments and international agencies is desired to permit scientists to carry on meteorological and hydrological research on forecasting and early warning

Knowledge Gap on Drought: More work is required on the complex nature of Asian Monsoon which contributes to drought situations. Farmers in most of the Asian LDCs are suffering from climate change induced droughts as well as uncertainties of precipitation.

In view of the observed gap in research and knowledge generation, conceptual *frameworks* need to be developed to study drought mitigating techniques to gain proper insights into different levels of vulnerability response to the extreme drought events. Scientific information need to be carefully gathered and analyzed on a longer timeframe to permit proper investigation of drought which is a complex phenomenon impacting all levels of LDCs with uncertain recovery period. It is therefore imperative on the governments of Asian LDCs to initiate country level studies on drought to evolve mechanisms on forecasting, early warning and mitigation process to reduce losses to human and property.

Modeling of Climate Change Extreme: The modeling results of extreme events showed significant upward trends in Bangladesh and if this trend materializes there will be increase in natural calamity causing destruction to life and properties and increasing the cost of adaptation. A majority of low lying non-embanked coastal areas may be completely inundated which will increase the risk of coastal salinity and scarcity of fresh water. Exposure to cyclone induced storm surges is likely to increase manifold.

Vulnerability Categorization: Climate models with medium confidence show that drought extreme could be most prominent in the 21st century in Bangladesh due to reduced precipitation and increased evapo-transpiration. Production of wheat, rice variety of HYV Aus and Boro may no longer be economically viable under climate change induced drought condition jeopardizing food security. This scenario dictates high priority to integrated drought management for Bangladesh.

Sea Level Rise (SLR): SLR is a possibility predicted by modeling (very likely) and Bangladesh, as a low lying coastal floodplain may face severe threat from SLR. There will be increasing risk of coastal salinity and fresh drinking water. Integrated coastal zone management plan for infrastructure development and development of salt tolerant crop variety should receive high priority.

Cyclonic Extreme: Modeling indicates increase in the depth and extent of storm surge induced coastal inundation intensified by increase in ocean surface temperature and rising sea levels (likely). Under the model predicted climate-change condition, the vulnerable area of cyclone prone zone would increase substantially. Disaster management plan in changing climate scenario will have to be redesigned to cope with this situation.

Capacity Building: Climate modeling involving different agro-ecological zones of Bangladesh is necessary to generate region specific adaptation plan for agriculture and economic policy. This is

presently at infancy due to lack of expertise, technology and scientific orientation. Government and international agencies should consider investment on capacity building for climate research.

3.1.3. Challenges Facing Bangladesh and Myanmar in Nurturing Marine Environment for Sustainable Development

I. Background

The marine environment of Bangladesh has vast potential for development through sustainable exploitation. Sharing the Bay of Bengal (BoB), neighboring Myanmar has similar potentials and challenges in preserving and developing the marine ecosystem. There is over exploitation of fishes and marine resources to meet increasing demand caused by increasing size of population in Bangladesh and Myanmar. Besides, discharge of polluted water from the continental area specially with industrial waste, agricultural pesticide, chemical dyes, oils etc are increasingly polluting the marine environment leading to sharp depletion as well as loss of biodiversity and unbalancing of ecosystem. There is inadequate investigation of this phenomenon to understand the status and change of marine environment.

Geologically BoB is filled by sediments washed down from the highlands, especially from the Himalayas shown in Figure-24 & 25. The ecosystem of BoB is characterized by its tropical monsoon climate resulting in high rainfall. Intensive fishing is the primary source of occupation of the people habituating the marine environment. The coastal and marine environment of BoB is under threat due to declining situation of marine environment (Aziz Ahmad et al, 1998). The BoB is a semi-enclosed tropical ocean basin, highly influenced by monsoons. In the BoB, there exist thermal domes which are associated with cyclonic circulation and up-welling (Ali, 1997).



Fig-24: Geographical Location of BoB in Bangladesh and Myanmar Coasts



Figure-25: The Sedimentation in the BoB

II. Dynamics of Marine Environment

Marine environment of the BoB plays an important role in the economy of Bangladesh and Myanmar. The BoB is an enclosed sea influencing the climatic conditions of South and Southeast Asian countries with monsoon weather. Major rivers like the Ganges, Brahmaputra, Meghna, Karnafuli, and Irrawaddy are draining huge freshwater to the BoB which make the bay very fertile. Marine fishery sector plays an important role in the economy of Bangladesh in terms of nutrition, income, employment and foreign exchange earnings. Alteration of marine ecosystem due to climate change has direct and indirect adverse effect on fish, flora and fauna for their reproduction, migration and survival. Reproduction of fish is one of their important life history trails, which is regulated by various exogenous and endogenous conditions. The reproductive cycle is a harmonious process interlinked with environmentally mediated routine of various aquatic ecosystems. Therefore, any adverse environmental conditions affect the natural reproductive process of the marine fish population and ultimately hinder the recruitment process to the stock through spawning and also the migration process.

The following are some of the changes observed in the marine environment of Bangladesh and Myanmar: -

- i. Oceanographic changes viz. high turbidity increased flooding, more tidal action and changes of salinity etc. which have accelerated the change of migration patterns of spawning, growth and its production. Changing of catch trends has been shifting to further deep seas.
- ii. Shifting of fishing zones to the deep seas resulted in poor catch due to inadequate number of deepwater fishing trawlers along with fish preservation facilities.
- iii. Increasing climate extremes especially frequent tropical cyclones and effects of El Nino and La Nina's southern oscillation create increased cyclonic activity in the BoB making the sea rough which in turn makes fishing difficult.
- iv. Piracy and fishing by other intruders are hampering fish production as well as catch and which in turn reduces economic benefits to Bangladesh and Myanmar.

- v. Withdrawal of water in the up streams as well as heavy siltation in the estuaries of the major rivers viz. the Ganges, Brahmaputra and Meghna have resulted in reduced availability of anadromous fish the *Tenulosa ilisha* (Hilsha). Pollution, both industrial and agricultural has also negative impact and substantially disturbed the spawning habitats. This caused social and economic crisis among the fishermen communities of the coasts.

III. Fish Resources in the Marine Environment

a. Fishing Grounds in the BoB

In the BoB within the territorial waters of Bangladesh there are four major fishing grounds as; i). South patches is situated between 20° 50' N to 21° 40'N latitude and 91° 00'E to 92° 50'E Longitude covering an area about 6,200 km, ii). South of south patches that lies between 20° 50' N to 21° 40'N latitude and 91° 00'E to 91° 50'E Longitude covering an area of about 6,200 km, iii). The Middle fishing ground is situated between 20° 50'N to 21° 20'N latitude and 90° 00'E to 91° 00'E longitude that covers an area about 4,600 km, iv). Swatch of no ground that lies between 21° 00'N to 21° 21'N latitude and 89°00'E to 90°00'E longitude which covers an area of about 3,800 km (Shohidullah, 1983) as shown in Figure-26.

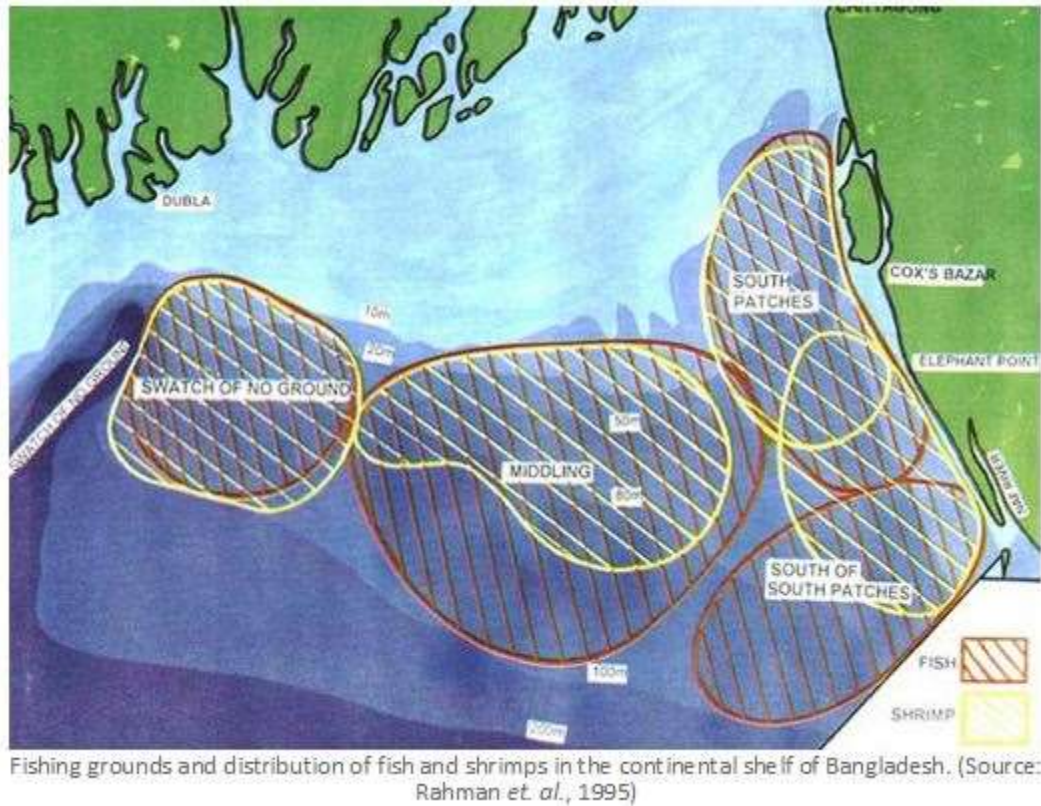


Figure-26: Fishing ground in the Marine Environment of BoB

b. Marine Fisheries

Marine fisheries sector plays an important role in the economy of Bangladesh in terms of nutrition, income, employment and foreign exchange earnings. The marine capture fisheries are exploited under multi-species strategy from the BoB and about 100 species are being exploited (White and Khan, 1985). The major species are finfish, shrimp, crabs, lobster, mollusks, starfish, cuttlefish, squid, snakes, turtles, crocodile and mammals (Khan, 2002; DOF, 2008). Marine fish production increased 1.12 million tons

(from 3.79 million tons to 4.87 million tons) between 2001 to 2007, but per capita fish consumption decreased because of increase in the size of population (Hussain and Hoq, 2010). The marine fisheries provide livelihoods to millions of people in the Bay of Bengal (BoB) region but the coral reefs are quite limited in the BoB due to high river discharge and turbidity. Alteration of marine ecosystem due to climate change has direct and indirect adverse effect on fish flora for their reproduction, migration and survival. Reproduction of fish is regulated by various exogenous and endogenous conditions. The reproductive cycle is a harmonious process interlinked with environmentally mediated routine of aquatic ecosystems. Therefore, any adverse environmental conditions may affect the natural reproductive process of the marine fish population and ultimately hinder the recruitment process to the stock through spawning and hampered the migration process. Use of unsuitable fishing gears that result in a high level of wasteful catch and destruction of egg bearing and juvenile fish need to be controlled. The marine fisheries resources are dominated by finfish and shrimp. The catch in 2005-2006 consisted of marine Hilsha (Clupeidae; 43.3%); shrimp (10.3%); Bombay duck (Herpodontidae; 8.20%); Jew fishes (6.78%); catfish (3.78%); pomfret (2.51%); sharks and rays (0.93%); Indian salmon (0.21%); and miscellaneous marine fishes (26.12 %). The major fishing grounds and their fishery are given in Table 5.

Table 5: Estimated biomass by family/group of marine fish in Bangladesh

Family/Group	Common Name (s)	Biomass (t) (% catch in parenthesis)
1. Sciaenidae	Croakers	20,670 (12.8%)
2. Ariidae	Cat fishes	18,729 (11.6%)
3. Nemipteridae	Threadfin breams	7,117 (4.4%)
4. Carangidae	Jack, Scads	5,039 (3.2%)
5. Mullidae	Goat fishes	4,811 (3.0%)
6. Synodontidae	Lizard fishes	4,663 (2.9%)
7. Trichiuridae	Hairtail/Ribbon fishes	4,043 (2.5%)
8. Leiognathidae	Pony fishes	3,998 (2.5%)
9. Pomadasyidae	Grunters	3,415 (2.1%)
10. Clupeidae	Serdines, Shades	3,109 (1.9%)
11. Scrombridae	Mackerels, Tunas	1,836 (1.1%)
12. Priacanthidae	Bullseyes	1,433 (0.9%)
13. Stromateidae	Pomfrets	1,348 (0.8%)
14. Cephalopods	Squid, Cuttle fishes	1,296(0.8%)
15. Engraulidae	Anchovies	1,082 (0.7%)
16. Gerridae	Silver-biddies	959(0.6%)
17. Harpodontidae	Bombay duck	783 (0.5 %)
18. Lutjanidae	Snappers	356 (0.2%)
19. Rajidae	Skates, rays	6,714 (4.2%)
20. Hilsa plus others		69,679 (43.3%)

The year wise total marine catch are shown in Table-6. (World Fish Center 2008)

Table 6: Production (MT) of fish from the Bay of Bengal

Year	Industrial	Artisanal	Total
1997-1998	15,273 (5.60)	257,545 (94.40)	272,818
1998-1999	15,818 (5.11)	293,979 (94.89)	309,797
1999-2000	16,304 (4.88)	317,495 (95.12)	333,799
2000-2001	23,901 (6.30)	344,596 (93.70)	379,497
2001-2002	25,165 (6.06)	390,255 (93.94)	415,420
2002-2003	27,954 (6.47)	403,954 (93.53)	431,908
2003-2004	32,606 (7.16)	422,601 (92.84)	455,207
2004-2005	34,114 (7.18)	440,483 (92.81)	474,597
2005-2006	34,084 (7.10)	445,726 (92.90)	479,810
2006-2007	35,391 (7.26)	452,047 (92.74)	487,438
Average	26,061 (6.30)	376,868 (93.70)	404,029

Note: The figures in parenthesis indicate percent of total

IV. Hilsa Spawning Pattern in the Bay of Bengal:

The global Hilsa catch is reported to be 75% from Bangladesh water, 15% from Myanmar, 5% from India and 5% from other countries such as Thailand and Iran. Hilsa is a highly migratory and anadromous fish (Fig:-27) with the same migratory and same breeding behavior as that of Atlantic Salmon fish (*Salmo* sp.). During last two decades Hilsa production from inland water declined about 20%, whereas marine water yield increased about 3 times. Major Hilsa to catch has been gradually shifted from inland to marine water. Hilsa fish ascend for spawning migration from sea into estuaries. It has been found that the major spawning areas have been shifted to the lower estuarine regions of Hatia, Sandwip and Bhola islands. Oceanographic changes viz. high turbidity increased flooding, more tidal action and changes of salinity etc. have accelerated the change of migration patterns of spawning, growth and its production.

Hilsa fecundity ranges from 1.5 to 2.0 million eggs for fish ranging in length from 35 to 50 cm. Hilsa fecundity is declining in different areas. Hilsa fecundity is declining in different areas due to climate change and the declining fecundity impacting greatly on Hilsa production. Due to shifting of the spawning ground at the lower zone, the survival rate of juvenile Hilsa is seriously affected. This declining of fecundity has natural impact on Hilsa productivity. During breeding season plenty of fully ripe and oozing male and female Hilsa were found and their ratio was 1: 1.6 at the spawning ground (Miah et al., 1999). About 80% of the female fish were found ready for egg realizing condition at the spawning ground (Hatia, Sandwip and Bhola islands). Major spawning is held during the full moon and new moon with high river flow the peak of spawning period in September and October (Miah, et. al., 1997). Due to various anthropogenic activities, climate change effect, increased siltation and rising of the river basins, the migratory routes as well as spawning grounds of Hilsa are disturbed, displaced or even destroyed. It has been found that the major spawning areas have been shifted to the lower estuarine regions of Hatia, Sandwip and Bhola in Southern region of Bangladesh. Oceanographic changes viz. high turbidity, increased flooding, more tidal action and changes of salinity, etc. have accelerated the change of migration patterns of spawning, growth and its production. The present fishing level $F=1.36 \text{ yr}^{-1}$ (where the $F_{msy}=0.6 \text{ yr}^{-1}$) and exploitation rate $E=0.70$ ($E_{msy} > 0.5$). It indicated that the exploitation rate of Hilsa population is in over exploitation level. The fishing level has become now near double than the fishing level where maximum yield could be achieved (F_{msy}) at the spawning ground (Miah et al., 1999, 1997, 1998). Therefore, in the long run the Hilsa population will be affected for getting maximum sustainable yield (MSY) from the BoB.



Fig: 27. Hilsa (*Tenualosa ilisha*)

The average annual production of Hilsa is around 3 million tonnes in Bangladesh (Fig. 28). In order to increase annual production, the GoB has been providing over 38.84 tonnes of rice in subsidy to 2.24 lakh fishermen. The government has also taken an initiative to introduce long-liner commercial fishing trawlers to catch fish from deep sea areas. The recent international arbitration has established the lawful rights of Bangladesh over 118.81 square km area of the sea. Taking this into perspective, the Government of Bangladesh (GoB) has already taken an initiative for preservation of marine fishery resources by imposing a ban on catching of all types of fisheries by commercial trawlers at the blue economics zone of Bay of Bengal for the first time in 2015. Under the welfare program, the government has distributed grants amounting to Tk 11.9 million during the past three years to the families of 247 fishermen who lost their lives while fishing in the sea due to natural disasters. Presently the Government has also taken some strong policy initiatives such as establishment of Hilsa Development Trust Fund for sustainable production of hilsa in the country. The production of the Hilsa has now reached 3.85 lakh tonnes which is worth Tk 170,000 million. As of 2015, the government has decided to increase the duration of the ban on catching brood Hilsa from 10 days to 15 days in the month of October for sustainable Hilsa production



Fig-28: Hilsa Landing at the sea shore areas which contributes 43.3% of the total marine catch in BoB

a. Catch Per Unit Effort (CPUE) in the Marine Environment

The catch per unit effort (CPUE) is steadily decreasing since the early nineties and the CPUE has decreased up to 50%. Currently 299 trawlers have been licensed for fishing in the BoB for deep sea fishing and the GoB has given license to 25 more trawlers for deep sea fishing. The two organizations, the Bangladesh Fisheries Development Cooperation (BFDC) and the Bangladesh Jatyo Matshyajibi Samabaya Samity (BJMSS) have started the process of mechanized fishing in the BoB. Besides, the some research initiatives have also been taken by the BFDC through commissioning a research vessel (Fig-29).



Fig-29: Fisheries Research Vessel M.V. SEAFDEC- in the Bay of Bengal-operated by BFDC

V. Marine Fisheries in Myanmar

Myanmar has diverse marine habitats, including coral reefs, seagrass beds, mangroves, sandy beaches and mudflats. Currently the threats facing Myanmar’s marine environments are – overfishing and the continuous use of destructive fishing practices (Fig-30). The Myanmar government has expressed its

commitment, through international conventions, to put 10% of its marine areas under protection by 2020 for protecting fauna and flora of its marine environment. In Myanmar, marine environment is jointly managed by the government departments and local fishing communities but the detail of which needs to be investigated at the field level.



Fig-30: Trawl Fishing by the Myanmar- Department of Fisheries

VI. Sea Food Products and Coral Reef in the Marine environment

Sea food products include live seafood such as live yellow eels, live mud crabs, chilled seafood, dried shark fins, fish maws, dried shrimps, dried fish, all types of black tiger shrimps, freshwater shrimps, white, pink and tiger shrimps, hilsha fish, silver pomfret, black pomfret, yellow croaker, cuttlefish, tongue sole, conger eels, kati fish, ribbonfish, red snapper, Indian mackerel, spanish mackerel. People in Bangladesh have limited habit of consumption of sea food. This along with limitation of transportation and preservation facilities results in inadequate human consumption of sea foods in Bangladesh.

Coral reefs and sea grasses are the most economically important resources of marine environment (Fig.- 31). Saint-Martin's island is the only coral reef island in Bangladesh. Around 10 species of coral reefs are found in the BoB (Haider and Mahmood, 1992). Sea grass bed also found at the Saint-Martin island (Islam, 1980).





Fig-31: Sea Food and Coral reef resources from Bay of Bengal

VII. Policy Priorities on Marine Environment

Livelihood of people: Employment and income from marine fisheries are contributing at least 20% of total fish production in Bangladesh while more than 90% of fish catch comes from artisanal fishing and the remaining comes from trawl fishing. Recent data on total catch in the Bay of Bengal has steadily increased for all fish types including Hilsha but the Catch Per Unit Effort (CPUE) data has declined up to 50% in terms of fish available. The CPUE increase calls for policy measures to increase fish stock through protecting spawners, nursery ground, reinforcing catch of immature fish with mesh sizes <10 cm for Hilsha.

Seasonal Occupation for Fishermen: Hilsha fishing is a seasonal activity while fishermen need year round occupation for sustenance. In absence of alternate occupation, they are forced to fish in the spawning season as well as catch undersized fish affecting total production. Occupational alternatives for fishermen during spawning season through training, developing micro-business activities on individual or cooperative basis of cottage products through facilitation of easy and low interest finance and marketing could have a positive effect on Hilsha and other fish production.

Protecting Spawners: Department of fisheries has a positive policy on protecting spawners through prohibiting catch during the peak breeding season (September-October) of the indicative spawning area in the Northern Bay. But this is subjected to many loopholes. Upgrading the policy through establishing seasonally closed protected areas and enforcing the same would greatly help in preserving spawners and increasing fish stock of Hilsha.

Marine Pollution: Marine pollution in the Bay of Bengal caused through industrial activities and ship breaking is a major concern affecting the marine environment. Environment friendly industrial practices and ship breaking can significantly reduce pollution to improve marine environment in the Bay.

Hilsha Laboratory and Hatchery: Presently, research on Hilsha fish breeding literally is non-existent in the country although 50-60% of the global catch of approximately 5 million ton is in Bangladesh. Investment of resources in breeding laboratory pointed to floating Hilsha breeding in the Bay may lead to improving breeding and production in the light of experiences of other fish breeding countries particularly in Nordic countries.

3.1.4. Floods in the Context of Environmental Changes and Sustainability in Bangladesh and Nepal

I. Background

Among the oldest and known disasters, floods have threatening humanities for ages (Ferreira, 2011). Around the world accelerations in population growth and changes in land use patterns have increased human vulnerability to floods. Harmful impacts of floods include direct mortality and morbidity and indirect displacement and widespread damage of crops, infrastructure and property. There are several types of floods: riverine, estuarine, coastal, catastrophic, flash, hill torrential or, the recent trend: skewed urban practices. Every year floods take thousands of lives, leave millions homeless and cause significant loss to properties and infrastructures all over the world.

II. Experience of Flood in South Asian LDCs (Bangladesh and Nepal)

Among the 14 LDCs in the Asia Pacific Region mostly affected by flood, Bangladesh and Nepal belonging to South Asia region are subjected to frequent moderate to severe floods of all types with adverse impacts on their people and economy. It is known that South Asia's geography makes it particularly vulnerable to natural hazards and disasters. The World Risk Index (WRI) published in 2011 shows that Bangladesh and Nepal display a high level of vulnerability due to their lack of coping and adaptive capacities and high level of exposure. According to WRI, among the 173 countries Bangladesh was ranked 6 and Nepal 99. Bangladesh has been declared the second most disaster-risk country in Asia with exposure of 27.52% while Nepal is 9.97% (WRI 2011). Analysis of history of disasters in South Asia reveals that Bangladesh and Nepal are the two densely populated LDCs that experience different types of flood every year with negative impacts on their people and economies. The plains of the foothills of Nepal and the entire floodplains of Bangladesh are mostly traversed by the rivers and tributaries mainly originated from the same source, the Himalayans. Both countries fall under the Indian Monsoon region with heavy precipitation during the wet monsoon that frequently cause severe floods destroying infrastructure, crops, vegetation and displace millions of people (Mirza, 2010). The aftermath of floods is water pollution, waterborne diseases and other epidemics. Loss of human life and livestock, escalation of prices, social insecurity and costs of rebuilding infrastructure are additional layers of constraints that affected regions have to bear after the floods along with resource diversion for immediate response, rescue, relief and early recovery activities (Ghatak et al 2012). Scientific projections affirm that risks of flooding will increase considerably in the main river basins of India, Bangladesh and Nepal. In Bangladesh, a rapid shift in extent and depth of flooding will occur with a global mean temperature rise of 2.6°C above pre-industrial levels. Widespread-glaciations in the Himalayas are likely to adversely impact the hydrological regime of the region (ICIMOD and UNEP, 2002, Regmi et al 2008).

a. Bangladesh

Among other South Asian countries, the geographical setting of flood risk is heavily concentrated in Bangladesh, causing high human and material losses. An average of 844,000 million cubic meter of water flows into the country during the wet season (May to October) through the three key rivers; the Ganges, the Brahmaputra and the Meghna (fig: 32). Most part of the country is low-lying and 80% of the landmass is flood plain thereby leaving the country highly vulnerable to the threat of repeated floods (Ghatak 2012, Choudhury 1998, Brammer 1989, Islam 1999).

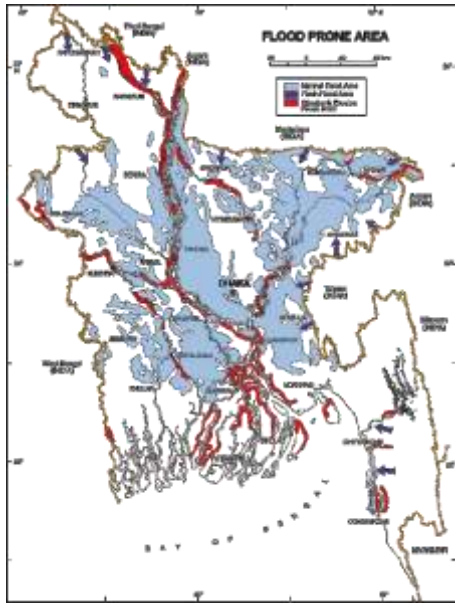


Figure 2: Types of Flooding

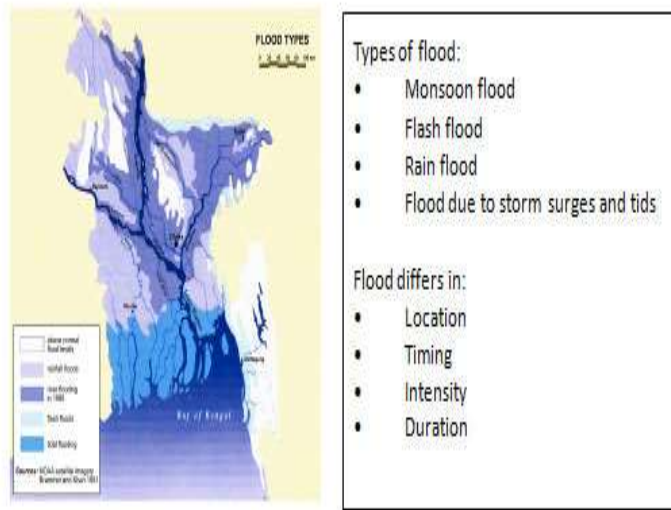


Fig: 32 Source: <http://mapofbangladesh.blogspot.com/2011/12/flood-prone-area-bangladesh.html>

Fig: 33 Source: <http://old.ddm.gov.bd/flood.php>

Flooding in Bangladesh is a normal and frequently recurrent phenomenon. The common types of floods in Bangladesh include flash floods from the overflowing hilly rivers, rain floods due to poor drainage, monsoon floods in the flood plains of major rivers and coastal floods following storm surge (fig: 33). The IPCC Special Report on Extreme Events (IPCC SREX, 2012) estimated that in a normal year, river spills and drainage congestions cause inundation of 20 to 25% of the country’s area, but in 1987, 1988 and 1998 floods inundated more than 60% of the country causing death toll to rise to thousands and leaving millions homeless. The 1998 flood resulted in 1,100 deaths and 30 million people left homeless (IPCC SREX 2012). The flooding pattern in Bangladesh points towards an increase in frequency over the years. Historical and recent data shows that during the past 40 years at least seven major floods have taken place in Bangladesh (Table 7). Some of the worst ones have occurred during the years of 1987, 1988, 1998, 2004 and 2007, making an average of one in six years (Ghatak 2012).

Table 7: Historical Floods in Bangladesh

Year	Affected people	People killed	Economic Damage (US\$ X 1,000)
1988	45,000,000	2,379	2,137,000
2004	36,000,000	No Data	2,200,000
1984	30,000,000	1,200	No Data
1987	29,700,000	2,055	727,500
1998	15,000,050	1,050	4,300,000
2007	13,771,380	1,110	No Data
1995	12,656,006	No Data	No Data
1993	11,469,537	No Data	No Data

Source: <http://www.preventionweb.net/english/countries/statistics>

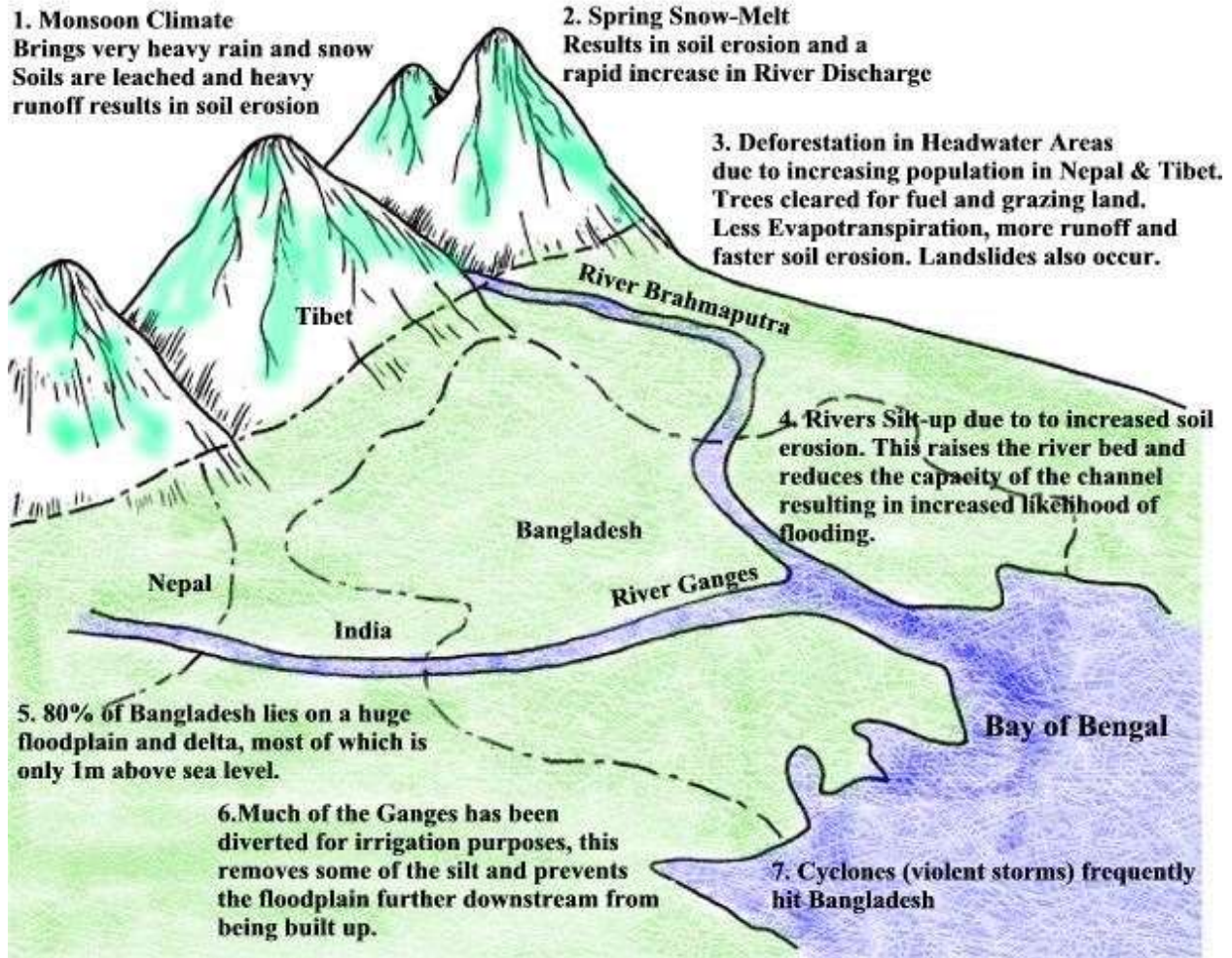
b. Nepal

Floods of 1985, 1993 and 2004 destroyed large tracks of land terraces, farm lands, pastures and orchards in Bhasedwa leaving the country food insecure (Dixit et al 2007). Nepal witnessed major flood in Tinao basin (1978), Koshi River (1980), Tadi River Basin (1985), Sunkoshi Basin (1987) and devastating cloud outburst in Kulekhani area (1993) which alone claimed 1,336 lives (Ghatak 2012). A flood at TinauKholan 19th August, 2008, affected 200 to 250 households with 500 to 600 individuals of Hattisud, Butwal Municipality affected.

III. Causes of Floods in Bangladesh and Nepal

Accelerated retreat of glaciers and increased intensity of monsoon precipitation observed during recent years have contributed to increased frequency of floods in Bangladesh and Nepal (Agrawala 2003). Monsoonal influences in particular are the major driver of floods in South Asia. Changes in rainfall patterns of the Indian monsoon due to climate change have increased the frequencies of high-intensity and prolonged rainfall. Ghatak *et al.* (2012) stated that generally, Bangladesh and Nepal receive the southwest monsoon that accounts for 70 to 80% of the rain fall from June to September. This skewed distribution of rainfall, two-third of which is received in 4 months span, results in overflowing riverbanks leading to flooding.

Some Causes of Flooding in Bangladesh



Source: <https://freshclick.wordpress.com/2009/03/27/causes-of-the-flooding-in-bangladesh/>

Nepal has more than 6,000 snow-fed and perennial rivers and rivulets and floods are a common occurrence every year. Most of those rivers originated from the Himalayas and after sliding from hills, flow through the Terai plains making the entire Terai floodplain prone to severe floods. During wet monsoon, these rivers swell and cause damages to the floodplain habitats. In last five decades, the Terai region witnessed a tremendous growth and development with infrastructure like roads, railways and urbanization which constrained the proper drainage of rainwater and thereby causing floods frequently (Dixit et al 2007). The impact of increasingly variable monsoons and intense rainfall in the floodplains of the Himalayas are catastrophic, affecting up to 1.5 billion people including 600 million in the Ganges river basin alone (Weisman et al 2011).

The probability of potential damages due to floods is likely to increase as a consequence of the increase in the intensity of extreme precipitation events due to global warming for example, up to above 100mm/day (Baida et al 2007). The Global Circulation Model projects a wide range of precipitation changes, especially in the monsoon, 14 to 40% by the 2030s increasing to 52 to 135% by the 2090s (Dixit et al 2010) and this is likely to cause more floods.

In Bangladesh, rapid population growth is creating an extra pressure on the land required for agriculture, settlements, and construction of roads and highways etc. and thus creating more flooding problem (Khalequzzaman, 1994). Due to unplanned urbanization the towns and cities are most vulnerable to floods especially during the non-stop rainfall even if it is for a small period (Rahman 2011).

IV. Flood Impacts

Floods in developing countries pose a greater threat to human life, health and well-being than in developed countries. In general, two-thirds of deaths directly related to flood events are caused by drowning and one-third by physical trauma, heart attack and electrocution (W. Du 2010). The most vulnerable members of the community are the elderly and the youngest ones who also often require special assistance (Dewan et al 2012). While economic losses are rising, direct deaths from flooding may be declining over time as measures to prevent flooding are increasingly being deployed.

The impacts of flooding in Bangladesh and Nepal are severe in both rural and urban areas affecting majority of the population, infrastructures, and family assets. Below is a discussion of some of the impacts of floods that were observed in this synthesis.

a. Personal security

In Bangladesh and Nepal, the major impact of floods is death, caused by drowning, water-borne diseases, diarrhea, snakebites, landslides and also by structural damages (Few et al 2004). During the 2007 monsoon floods in Bangladesh, snake bites were estimated to be the second most significant cause of death after drowning and contributed to more deaths than even diarrheal and respiratory diseases (ICHARM 2008).

Other major impacts result from being traumatized by witnessing death, loss of employment and access to basic needs such as getting adequate supply of fuel required for cooking in urban, semi-urban and rural areas. Fuel such as cow dung, jute stick, wood that are used in rural areas are usually all washed away or become wet making these unusable while in urban area, the water damages the gas pipe line leading to non-availability of gas for cooking (Dewan et al 2012, Ninno et al 2011). Further, day laborers often starve to death due to staying a long period with no work or due to sickness. During the 1988, 1998 and 1999 floods in Bangladesh hundreds of industries, especially garments factories went under water which destroyed raw materials, machineries worth millions of dollars and some factories never recovered. Due to this, thousands of workers went unemployed leaving the country dependent on foreign aid (NAPA 2005, Ahmed 2012, Dewan et al 2012).

Direct impacts occur through the increased floods, drainage congestion and water logging as well as infrastructure damage during extreme events. The important urban sectors that suffered severely by the floods include urban infrastructure, industry, trade, commerce and utility services etc. As consequence, it hampered usual productivity during and after major floods and hence increased the vulnerability of the urban poor by many folds (Denissen 2012).

A major tourism destination in western Nepal faces increased risk of natural disasters following a devastating flood, sudden flood on the Seti river, which killed more than 60 people, has brought changes in the course and flow-pattern of the river (Denissen 2012).

b. Buildings and Infrastructures

Research shows that the impact of flooding on housing and households can be extensive. Fast flowing floodwaters are capable of washing away entire slums while the slow rising water damages buildings (USACE 1988). In rural area of Bangladesh houses with “Mud Walls”, “Coconut leaf Walls” and “Tin Walls” collapse leaving people and assets exposed and vulnerable. About 32% of total population in Bangladesh lives in slums (Miyan 2012, Rahman 2011). A large number of people are left homeless and stranded for days due to flooding. In Nepal 20% of Nepalese live in urban area, one of their direct impacts of flooding includes physical damage caused to buildings.

According to Jha *et al.* (2012), damages caused to public buildings such as hospitals, clinics, educational buildings, and significant cultural sites such as mosques and temples can lead to further indirect impacts. For example, the disruption to education could contribute to poor performance long after the flood incident. Similarly, there is likely to be a reduction in the capacity for providing both immediate and longer term healthcare and support in Nepal. During the flood most of the roads become unusable and or partially destroyed. The city waste management system is negatively affected with garbage scattered all over clogging drainage system and polluting environment in both Bangladesh and Nepal (Jha *et al* 2012, NAPA 2005, Moench 2004).

In Nepal cloud outburst in low monsoon weather system in 1993, affected the catchments of the Gandaki river system and caused great Bagmati flood which damaged the Kulekhani Hydroelectric project and the Bagmati barrage (MoWR 1993, Dixit *et al* 2007).

c. Crops and Animals

Bangladesh and Nepal have large agrarian economy. In Nepal the agriculture sector provides over 30% of country's GDP and supports more than 86% of the population, whereas in Bangladesh agriculture comprises about 18.6% of the country's GDP and employs around 45% of the total labor force (Weisman 2011). Majority of the poor in these two countries live in areas of high risk to floods and landslides and are more reliant on local natural resources. In Nepal, monsoon floods result in inundation and sand deposition over large areas and thus damage crops and land resulting in long term food insecurity.

Rice and wheat are staple foods in both countries. A special type of rain fed rice, “Aman” grown in Bangladesh is highly susceptible to river floods and has been affected in all years of flooding (Baky *et al* 2012). During the Bangladesh 1998 floods, 69% of *Aus* rice production, 82% of deep water *Aman* and 91% of transplanted *Aman* were lost leaving the whole country food insecure (Ninno *et al* 2001). Usually most of the floods occur during the wet monsoon (July-August) and severely affect the summer vegetable crops specially the creeper and climbers e.g. cucumber and bitter gourd. Floods in Bangladesh also affect small agriculture farms such as mushroom industries. The whole mushroom industry was seriously affected by the floods of 1998 and 2007 causing huge loss of foreign currency (IPCC 2007).

Within rural and semi-urban areas the impacts of flood are severe on domestic animals like poultry and dairy which are the major sources of earning. Cultivated fish (catfish, shrimp and carps etc.) drift away due to erosion of embankments and boundaries of the lakes or ponds and resulting in economic losses to the fish farmers as well as export industry of Bangladesh. Both Bangladesh and Nepal are developing countries and a large portion of food supply depends on agricultural production. Due to flooding leading to losses in crop yield, dairy, poultry and fisheries, these countries are driven to depend on foreign aid (Weir 2009).

V. Coping with Flood

Government and NGOs both in Bangladesh and Nepal have initiated a number of activities to minimize the adverse effects of floods. According to the NAPA report (NAPA 2005), the GOB has established an inter-ministerial committee on climate change headed by Minister for Environment and Forest (MoEF) and with representation from relevant government ministries and department as well as NGOs and research institutions. The Department of Environment (DoE) under the MoEF has also set up a Climate Change Cell within the government to work on mitigating flood and other disasters.

In addition to constructing 5,695 km of embankments including 3,931 km long coastal embankments to protect coastal land from inundation, GOB has dug 4,774 km of drainage channels for proper flow of flood water. They also constructed 200 flood shelters for evacuation of people threatened by floods [28]. In Bangladesh, people along with their domestic animal usually take shelter in schools, colleges, Union Council complex, Killas (3-4 metre elevated parcel of earth) and even on the embankments of the rivers. GOB and different NGOs have taken initiatives to build brick latrine with proper septic tanks to minimize water contamination. In Nepal, tube-wells with pipes of long height (above flood level) have been built so that drinking water is available during floods (NAPA 2005). In the last decade, Bangladesh and Nepal Governments and NGOs organized different relief programs e.g. Gratuitous Relief (GR) in Bangladesh, Vulnerable Group Feeding (VGF) in Nepal to help the flood victims (Ninno et al 2001).

Recently in Nepal, besides government efforts, NGOs have started different programs to build awareness to the community through different activities. Activities include immediate response during flood, training for preparedness, training for flood response activities, providing information of flood shelters and for post rehabilitation through distributing pamphlets, posters and other materials for assisting with emergency relief (monetary and non-monetary).

The traditional and indigenous practices of coping with floods are as important and vital as the modern approaches. Households adjust to the shock of a flood disaster in several ways such as reducing expenditure, selling assets. One major coping behavior is borrowing which is common among women although borrowing is not a long term solution (Ninno et al 2001).

In Bangladesh farmers reduce flood impact by cultivating deep water rice known as “Jola Rice” which has proved to be resilient to even to severe floods. To reduce the impact of flooding on homesteads, traditionally people raise the homes by digging ponds around the house. It is important to note that the pond that is dug to uplift land also serves the purpose of securing portable water for use during flood. Moreover, ponds hold excess water from the wet monsoon and are also used for fish and aquaculture (Dewan et al 2012). Besides ponds, other practices are terracotta pitcher and bottle Gourd Shell pot are still used for saving drinking water in flood season in Bangladesh.

Regardless of their volume, floods affect infrastructures and leave citizens commuting less. In Bangladesh, traditional practices for commuting in rural and semi-urban is to build “Vela” a float made of either Bamboo or Banana tree, and/or using small hand rowed boats. Although shelters are organized by the government, often it is not enough to accommodate all the flood victims and the traditional practice, to create “Matcha” elevated surface made out of bamboo or woods or use the “Vela” to live until otherwise is still valuable.

In Both the countries, although government does organize relief with food, cloth, money and healthcare services these usually do not reach the victims in time due to transportation problem. However, traditionally people of the flood prone area used to keep or store puff rice (Muri), flat rice

(Chira) and jiggery as immediate food supply during the flooding period to protect them from starvation and these dry foods are safe and hygienic. Green coconut water is used both in Bangladesh and Nepal to rehydrate the victims of waterborne diseases like diarrhea, cholera and dysentery (Dewan et al 2012).

In Nepal, traditional flood forecasting, early warning system and community based flood management saves many lives and properties. Some of the indicators for the people for forecasting heavy storms include position of the cloud in the sky, extent of rainfall in upper catchments, mobility of ants, abnormal fly bite, abnormal crying/voices of animals and birds, intensity of thunderstorm and wind, position of stars, and magnitude of hotness. Strange sounds from river/torrents, muddy smell in the water, rising level of water flow are some indicators perceived as early warning of flood (ICHARM 2008). These local knowledge are the most valuable asset for any flood management planning in Nepal. Communities apply pre-flood preparations as part of the flood management. These include management of basic materials in advance, psychological preparedness for floods, collection of non-timber forest products (NTFPs) to treat livestock, creation of small drainage in each plot of land and storage of the valuable materials in *aati/attaiya* (attic). Other practices include storage of the valuables in *attaiya*, preparation of the *khatiya/palang* of bigger height, Weaving Doko (big bamboo basket) to save poultry from flood, storage of grains and dry foods, preparation of informal self plan for evacuation, arrangement of evacuation place, and management of livestock in advance and making of temporary aatiya (attic). Similarly, procurement of essential drugs in advance, management of firewood, storage of dry food for livestock, construction of pihan (cooking stand), arrangement of evacuation place and plan, drainage improvements, homestead raising, and increase of the height of hand pumps are other activities people perform as part of their preparedness to flood disaster. They use tents and plastics to live, manage proper places for livestock, aware children not to swim in the muddy water and fill sand bags to divert the flood. Immediately after the flood, there is a general practice to assess damage, dry grains and clothes, construct/repair the houses, and manage food and clothes. Likewise, maintenance of tube well for drinking water and use of local treatments to manage the water borne diseases are other practices taken by the community to cope with the flood disaster.

The Hyogo Framework for Action (HFA 2005-2015) on Building the Resilience of Nations and Communities to Disasters provides the latest framework and strategy for disaster risk management. Both Bangladesh and Nepal signed the HFA and thereby committed themselves to achieve the HFA's objectives and priorities by 2015. Bangladesh Disaster Management Bureau prepared the SOD in 1997 which was further developed in 2010. The key roles and responsibilities particularly of Disaster Management Committees (DMCs) have been divided into two major categories: 1. Risk Reduction; 2. Emergency Response - During warning period, - During hazard onset and - Post hazard period.

Efficacy of these preventive practices is hardly documented.

VI. Flood and Forest Trees in Bangladesh

Since mid 1970s, Bangladesh Forest Department, NGOs, private organizations and individuals have planted about 10 millions of trees per year. However, during the plantation, they hardly take into consideration the habits and habitats of plants showing preference for fast-growing and exotic plants. The exotics plants include varieties like Acacia, Eucalyptus, Epil-epil, Mehogany and Albizia species. The more enduring and environment friendly varieties are the indigenous one which includes Mango, Neem, Gamar, Jackfruit and some medicinal plants. During the floods of 1988, 1998, 2001, 2004, 2006, 2008, 2009, 2010 and 2011 the plantations were seriously damaged and innumerable plants died. In one study relating to the death of huge number of *Dalbergia sissoo* trees (fig 34 and 35), it was observed that in

some of the monoculture plantations the incidence of death was as much as 64% and the lowest rate was about 22% of the planted trees. The data on death of trees in different districts of Bangladesh can be seen in figure-36. It had been observed that in the roadside and strip plantations including community forestry, large number of plants were badly affected due to floods and water-logging. This was a great loss in terms of money and also in consideration of environment. This calls for initiatives at policy level to make choice of plants in terms of habits and habitats for plantation in a flood prone country like Bangladesh.



Figs. 34 & 35 Massive Death of *Dalbergia sissoo* trees at Kushtia-Rajbari road

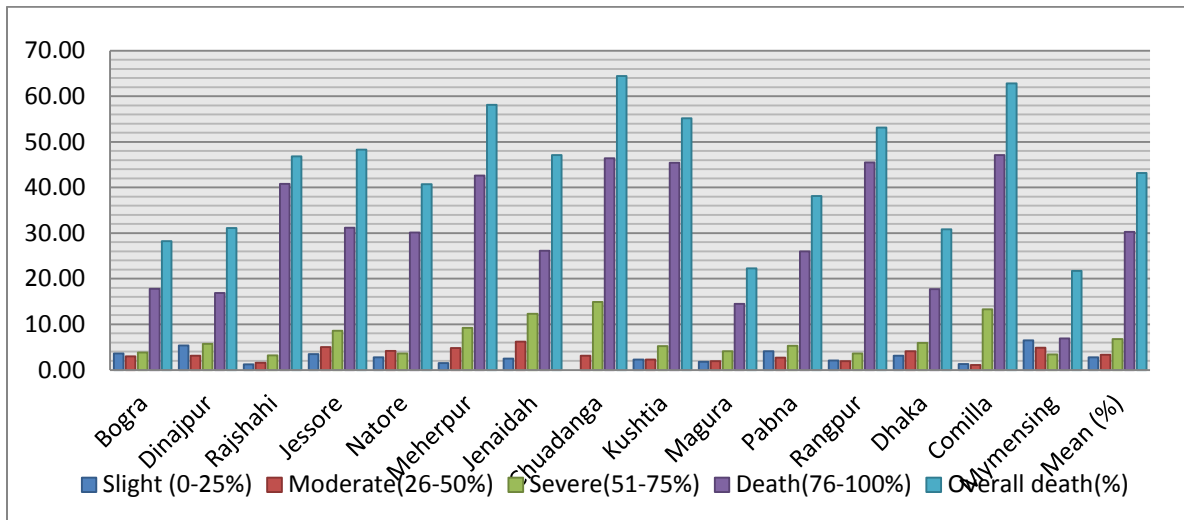


Fig. 36 Status of death of *Dalbergia sissoo* in several districts of Bangladesh (Year 2001)

Although some isolated studies have been conducted but there is little record on the number of damaged plants due to floods and water-logging.

VII. Flood Policy Priorities

Standing Orders on Disaster (SOD): Bangladesh has developed SOD to cope with flood disasters for flood risk reduction and emergency response during warning, hazard and post hazard phases. SOD has

limited reflection of traditional wisdom and practices and community involvement which can be corrected through policy revision.

Flood Shelter: The ongoing practice of constructing flood shelters in the form of schools, madrasahs, and community centers, local government offices by the government and non-government organizations (NGOs) should be reinforced through making a nation-wide policy for living with flood.

Flood Resilient Housing: Fast flowing water washes away most houses constructed with mud, leafs and corrugated iron sheets in rural areas destroying assets and making people homeless. Developing housing codes for non-engineered structures could contribute to flood resilient housing.

Environmental Impact Assessment: Poorly planned construction of roads, embankments, canals and water reservoirs interrupts the natural water flows accentuating flood in many areas. Policy of mandatory environment impact assessment prior to construction of such structures could preserve natural water flows and reduce flood damage.

Community Integration: Bangladesh is a low lying delta and people have been coping with flood through using their hereditary wisdom and practices. These need to be integrated in NAPA through field research on these and also through assessment of actions initiated by the community on flood warning.

Choice of Plant: Indigenous plants have been found to be adapted to adverse situations created by flood and water-logging, however, plant varieties imported from other continents (*Acacia mangium*, *Eucalyptus camaldulensis*) are causing loss to plantations. Due to lack of information, farmers choose non-adaptive exotic varieties. Business interest as opposed to environment dominates import of species in private and public sectors. Most of the indigenous varieties are being eliminated from species list of the Department of Forestry. This needs to be reversed through policy intervention and scientific investigation of habits and habitats of plants to flood-prone condition.

Plantation Site: Growing plants according to adaptation requirements of every plant species to specific climate and physiographic conditions can reduce damage to plants due to floods. This aspect is largely ignored in growing site-specific plants particularly in organized plantations by Department of Forest, although Bangladesh is flood-prone and subjected to water-logging. Development of a policy framework on site specificity of plants has potential of improving the situation.

Flood-Resistant Tree Crop: Flood-resistant tree crops can be of particular benefit to flood conditions in Bangladesh. Such trees have been identified in neighboring India (e.g. *Acacia nilotica* and *Neolamarckia cadamba* etc.) and Pakistan (e.g. *Albizia procera* etc). Government may consider allocation of resources to engage scientific community in identifying flood-resistant tree-crops for Bangladesh.

3.1.5. Coastal Zone Management in Bangladesh

I. Introduction

Coastal zones are the interfaces of land and ocean balancing geosphere, atmosphere and biosphere. These are major biological activity centers congenial for easy living and around 3 billion people reside in the coastal zones of the world (Enemark, 2007). Coastal zones are highly productive with important sources of food and raw materials, energy, minerals, recreation, transport, and trade and these are created through accumulation of huge geochemical substances which are the results of hydrological cycles consisting of rivers and distributaries originating from the land and ocean currents and waves. Coasts also host an impressive array of valuable habitats with an equally extraordinary collection of

species (Bird *et al.*, 1979). Excellent landscapes are found on sea shores where many spas and recreation zones are located. At the same time, wide and clean sea beach are located near green coastal forests shrubbery including mangroves, palms and nuts which are of particular value. These are the most effective natural defense for keeping the shoreline intact from abrasions (Astaniin et al. 1983).

Bangladesh has a large coastal zone along the BoB that provides highly productive sources of terrestrial, oceanic and marine resources. Its coastal areas are one of the most poorly studied areas of the world although it possesses high potential for economic development. The Bay has substantive potentials for development from local as well as global perspectives (Islam, 2003).

The coastal zone of Bangladesh is comprised of fertile land, river estuaries, mangroves, seashore and islands adjacent to the land-water interface of southern part of the country with a great diversity of natural resources including coastal and marine biodiversity, scenic beauty, fisheries, forests, salt, minerals, easy transportation and sailing facilities, as well as high potential for exploration of both onshore and offshore natural gas. It harbors ports, tourism facilities, and other development opportunities and affects the livelihood of about 50 million people. Although Bangladesh is most vulnerable to frequent disasters like floods, cyclones and droughts but historically, the people have adapted to these, making their homes and homesteads safe following disaster resilient traditional practices; adopting climatic-season-based cropping, fish-farming, transportation by boat, traditional flood plain management, and natural and traditional defense mechanisms. However, over the last few decades with increasing urbanization, unplanned road construction, industrialization and population growth, many aspects of traditional life have been changing very fast (Rahman, 2011).

Coastal population, including three million inhabitants of the 72 offshore islands, is extremely vulnerable. About 18% households of the southwestern coastal zone are dependent on resources of the Sundarbans, viz. shrimp-fry, honey, Golpata, mollusks, shell, crabs and medicinal plants etc. Because of increasing rough weather in the Bay, about 0.5 million people, dependent primarily on fishing, are losing their works. Over 160,000 coastal fishermen and 185,000 shrimp-fry collectors involved in marine fisheries are threatened due to cyclonic disasters and tidal surges and reduced fish and aquatic resources (NPDM-2015). According to a recent study of Soil Research Development Institute (SRDI), it is found that Sundarbans has lost 8.3% area (about 50,000 ha) of its northern front due to deforestation for shrimp culture during the period of 2000 to 2010. This destruction has been done by clear-felling of mangrove trees and creating un-noticed pockets (The Daily Star, September 16, 2013). As a result, the pockets have become low depression zones and more vulnerable to climate-induced cyclones and tidal surges.

Such losses are caused by recent changes in the coastal zones through human pressure, misuse of resources, introduction of inappropriate technologies; industrial and agricultural expansion and pollution. Vulnerabilities in the coastal zone are increasing with accentuations of natural hazards caused by environmental degradation, climate change and human activities as well as exploitation of mangrove. Coastal zones have already been affected by land erosion, salinity intrusion and loss in biodiversity. The potential threats are going to be even worse in future. Due to climate change effects, the incidences of tropical storms and tidal surges have been increased in the coastal belts of Bangladesh, India, Myanmar and Sri Lanka. The vast coastal zone is facing increasing vulnerability due to multiple stressors such as environmental degradation and climate change which needs to be explored to identify causes, effects and reformative measures.

II. Environmental Change: Natural and Anthropogenic

With the environmental change, agriculture has been suffering from uncertainty and having disasters from floods, droughts, salinity, cyclones and hailstorms and cropping is being hampered due to erratic precipitation pattern; and it has been predicted that rice and wheat production will reduce 8% and 32% respectively by 2050 (Bhattacharya 2013) and fisheries are also expected to be impacted negatively .

Increased precipitation brings more water in the catchments which are beyond the drainage capacity, causes damage of infrastructure and drainage congestion in the urban areas due to faulty drainage and insufficient channels (Biswas et al 2010). Salinity intrusion hampers irrigation, domestic use and drinking water. Trans-boundary withdrawal of water disrupts hydrological cycle and cause increased rainfall during the pre-monsoon, wet monsoon and post-monsoon in upper catchments and/or within Bangladesh leads to more floods and water-logging; causes more river bank and coastal erosion (CCC, 2009, Bangladesh: State Of The Environment 2001, Rahman 2004).

Faced with natural disasters, using government and donor funds, considerable investment has been made in flood control works in the form of embankments, roads and highways which has blocked traditional navigation routes and water flows. These measures including embankments and polderization (fig 37) as well as unplanned afforestation have negative impact on environmental condition in the coastal zones. Poor maintenance and inadequate management of the polders have also contributed to internal drainage congestion and heavy external siltation. As a result, soil fertility and agriculture production in some areas of the coast are declining because of water logging and increased salinity inside the polders (BWDB 2013). In 2008, IWM studied the impact of Sea level rise in coastal rivers of Bangladesh and assessed the change in the tidal characteristics of the surrounding rivers due to sea level rise and its impact on inundation area of the polder. Studies reveal that high water level at the surrounding rivers of polders increases in the range of 30-80 cm for sea level rise of 32 cm and 88 cm respectively and hampered the smooth drainage of the polders.



Fig: 37 Polderization Under Threat, Source: <http://reliefweb.int/>

Prolonged water-logging affected cropping, thick wind-barriers increased the wind-speed and damaged the structures; uprooted trees damaged buildings, transmission lines, bridges and agricultural crops. However, increased awareness has significantly reduced the death tolls (Rahman 2011).

Embankments, polderization, coastal afforestation and shelterbelts, construction of shelter-house are important activities for protection against calamities. But in most cases these are constructed against the natural forces nay unscientifically and inefficiently. Embankment and polders have caused

permanent water-logging in many parts of the coastal zones. Many coastal polders, constructed to protect agricultural land from saltwater inundation, were subsequently turned into large shrimp farms. Saltwater was allowed into the polders in order to raise shrimps. Driven by commercial interests, the land used for agriculture and mangroves was converted, often forcibly, to shrimp farming (Haque 2004) leading to many land-use conflicts (Karim 1998, Deb 1998), environmental pollution and social unrest (Firoz 2003, Rahman 2011, Miyan 2012).



Figs. 38 Coastal erosion due to shrimp hatcheries in Cox's Bazar

Shrimp hatcheries pose a great threat to coast line. Cox's Bazar, the world's longest sea beach, is under threat of erosion due to disposal of effluents from the shrimp hatcheries (Fig. 38). Moreover, expansion of sea beach hotels, motels and recreation zone by cutting shoreline hills has destroyed a great part of the beach which needs immediate attention to prevent further destruction (Rahman 2011, Miyan 2012).

III. Coastal Green Belt

Dense forests can attenuate wave velocity (Mascarenhas 2006). To protect local, coastal and regional areas from storms, cyclones, tornadoes and tidal upsurges it is essential to reduce the wind speeds by planting appropriate tree species those can withstand the high speed wind and break the wind speeds. Naturally grown halophytic plants e.g. Sundri (*Heritiera minor*), Geoa (*Excoecaria agallocha*), Goran (*Ceriops* sp.), Kankra (*Bruguiera gymnorhiza*), Khamo (*Rhizophora mucronata*), Baen (*Avicennia officinalis*), Keora (*Sonneratia apetala*) and Kushi (*Aegiceros majus*) etc. have the special adaptation for withstanding in the littoral zones with clayey alluvial soil, tides and strong salinity and winds. There are several palm species e.g. Golpata (*Nipa fruticans*), Hital (*Phoenix paludosa*), Coconut (*Cocos nucifera*) and Cane (*Calamus tenuis*) and some swamp elephant grasses (*Typha angustata* and *T. elephantiana*), *Alpinia allughas* and screw pine (*Pandanus facicularis*) etc. have the soil binding capacity and control erosion. These also reduce the speed of tidal upsurges. Moreover, these maintain a gradual hierarchy and reduce the speed of the strong winds. Most of the palms can withstand winds at a speed more than 250 km/hour. They can easily break strong wind-flow and reduce the speed (Rahman 2012).

With the above context in view, from 1966 the Forest Department developed mangrove plantation program outside the protective coastal embankments for eastern coastal area. The program received additional impetus from the evidence of the Sundarbans natural mangrove forests which provided effective protection from wind and waves for the western coastal areas. Quite naturally, it has been expected that the plantation of mangrove would give a worthwhile degree of protection to other coastal areas of the country open to the sea. The Coastal Afforestation Scheme had been operated from 1966 to 1974, and established 4,745 hectares of plantations; the project was extended to 1980, by which time another 29,700 hectares were raised. All these plantations were concentrated on the offshore islands

and new accretions. The afforestation species were Keora (*Sonneretia apetala*), Baen (*Avicennia officinalis*), Kankra (*Bruguiera gymnorrhiza*), Golpata (*Nypa fruticans*) and Gewa (*Excoecaria agallocha*).

Recently, it has been observed that the coastal green belt has been undergoing indiscriminate destruction and encroachment due to human activities. The administrative machinery of the government as well as the community efforts have not been able to contain this type of destructive behavior. A program of participatory mangrove plantation involving nearby coastal communities, which has proved successful in other countries, could be a sustainable mechanism to protect mangrove forests. This mechanism is being actively considered within the Forest Department.



Fig. 39 Thick windbreaks in the coastal embankments of Barishal

Thick shelterbelts on the embankments and along the roads and highways although protect the coastal zone but it causes adverse effect by increasing wind speed as per Pascal's law and pass through the passages like river with high speed (Fig. 39). In both cyclones Sidr and Aila this effect increased the wind-speed of the cyclones and caused more damages in the interior region especially where shallow water-bodies for shrimp culture were made by removing mangrove forests (Rahman 2012).

IV. Selection of Species and Methods of Afforestation

Massive plantation was done without caring their habit and habitats and disrespecting natural adaptation processes, millions of exotic trees especially the *Acacia* spp., Raintree (*Albizia saman*), Mahogany (*Swietenia macrophylla*), Royal Sirish (*Albizia richardiana*) and *Eucalyptus* spp. etc., were planted in the coastal embankments and in the homesteads replacing the indigenous species. However, still there lies problems with the selection of species, it has been studied that the species planted along the coastal embankment are not according to their habit and habitats, on many occasions the damage during the cyclones increased because of inappropriate of choice of species (Rahman 2011).

Moreover, during the plantation, the optimum spacing was not followed and the safe distances were not maintained. As the trees are shallow-rooted and in the high water-table zone the root system could not develop for proper anchorage and thus during the cyclonic storms and tornadoes they were uprooted and damaged the structures and utilities and crops. The post-Sidr study showed that about 16.84 million woody and fruit trees were uprooted by Sidr. Haq (*et.al.* 2012) claimed that due to raising saplings in the earthen pots the taproot system could not develop which is found to be contradictory in field observations as it is solely an adaptive practice of habit and habitats of the plants (Rahman 2012). So-called Sorjan planting system is not a new practice as the people traditionally excavated several ponds in every home for landscaping to make their homes and to grow trees on raised lands.

Plants absorb millions of liters of water every day and about 95% of water transpire to the atmosphere using 5% only (Verma 1999, Rahman 2013) and thus the plants keep the atmosphere humid and maintain the hydrological cycle through transpiration and precipitation. Physiological studies revealed that Eucalyptus as a xerophytic plant has a low transpiration rate and control stomatal opening according to water availability (Kumar 1994, Brown et al, 1976, Ackerson 1980, Sing et al 1990). Similarly comparisons have been done among xerophytic *Acacia auriculiformis*, *A. mangium* and native *Pterocarpus indicus* and observed that the stomatal size is almost half in case of *A. auriculiformis* and *A. mangium* than that of *P indicus* (Combalicer et al 2012). Verma (1999) also reported very low transpiration of *Acacia* sp. Thus it is proved that these exotic species provide less transpiration and impacts upon humidity and low precipitation in the region and thus huge Eucalyptus and Acacia species are causing dryness and changing the climate. Moreover, these exotic species do not provide food and shelter for birds and wild-lives and do not favor undergrowths. Thus, choice of indigenous plants and mangroves could have brought healthy environment in the coastal zones.

V. Destruction of Mangrove Forest

Since 1980's the mangroves of the South and South-western coast has been indiscriminately destroyed and the land was excavated for shrimp and fishery projects. These shallow large ponds holding saline water raise the local temperature and create pockets for low pressure depression and it is one of the major causes of huge damages of Sidr-2007 and Aila-2009.

It is to be noted that mangrove forests were developed by the Forest Department following the pattern of Sundarban in the eastern and north-eastern coasts involving Chakaria Sundarban at Cox's Bazar and areas around Sitakund, Baroawlia, Bhatiari and Kumira in Chittagong over the BoB coast. The Chakaria Sundarban has been adversely affected by shrimp cultivation which is still continuing. The ship-breaking industry which has been developed in the Sitakund area not only destroyed the mangrove forest belt but also has a very negative impact on the entire coastal zone through pollution.

In both these activities, involving shrimp cultivation and ship-breaking industry, environmental consideration should prevail to protect the coastal zone.

VI. Industrial and Commercial Activities in the Coast

A ship-breaking activity is a threat to both the terrestrial and marine environment as well as to public health. It is like a mini version of a city that discharges every kind of pollutants a metropolis can generate like liquid, metal, gaseous and solid pollutants. Oil films on water reduce the exchange of oxygen and carbon dioxide across the air-sea interface which is harmful to aquatic life. It also causes damage to the bird population by coating their feathers with oil which causes buoyancy and insulation losses. Sometimes spilling may cause wide spread mortality amongst the population of fish, mammals, worms, crabs, mollusks and other water organisms. Furthermore, oil spilling may cause serious damage by reduction of light intensity, inhibiting the exchange of oxygen and carbon dioxide across the air-sea water interface, and by acute toxicity. As a result the growth and abundance of marine organisms especially plankton and fishes may seriously affected. Indiscriminate expansion of ship-breaking activities poses a real threat to the coastal inter-tidal zone and its habitat (YPSA 2005, YPSA 2010, Rahman 2011, Miyan 2012).

Moreover, cutting of hill and hillocks for industrial establishment in Chittagong, is causing a great land area loss and exposure of the rocky strata. Some folded ranges in Cox's Bazar are being cut for residential accommodation. The coast line of Cox's Bazaar has been dug for shrimp-culture which will in

the long run make the coastal belt vulnerable to sea current erosion. Hill-cutting may cause land-slides, faults during earth quake.

Unplanned development of resort area after cutting the hills and establishment of shrimp hatcheries along the coast threatens the beach with erosion, while waste from tourists and vendors are damaging the aquatic habitat. About 15 km of the Cox's Bazar beach is at high risk of erosion, especially the shrimp hatcheries at Himchari and Kolatoli, and also motel and hotel zone, and the Diabetic Hospital areas of Kolatoli. A half of the Kolatoli village has already been lost to erosion due to unplanned discharges of water to the sea from 55 shrimp hatcheries (The Daily Ajker Deshbidesh, October 16, 2008). Sea current has damaged 3.4 km of beach of the Old Marine Drive Road from Kolatoli to Himchari in Cox's Bazar (Rahman 2011). All these industrial and commercial activities carried out in the name of development are to be adjusted to conform to the prevailing environmental laws as well as good practices for sound coastal zone management.

VII. Traditional Adaptation Practices

Since the Tropic of Cancer has passed through the center, Bangladesh is very prone to tornadoes due to wide-spread terrestrial wet-bodies all over the country; the coastal zone is more prone to tornadoes and cyclonic storms. The coastal zones have excellent natural defense systems with Arakan hill ranges along Chittagong and Cox's Bazar shoreline, strong windbreaks with hill forests in the eastern coast of the Bay of Bengal. Sea currents, web and tides and upstream fresh water flows play very important roles for enriching the coastal zones of Bangladesh (Rahman 2010). The Sundarbans is the world's largest Mangrove forests, the National Park of Bangladesh, has been declared as Tiger Reserve in 1973, UNESCO World Heritage Site (UNESCO-1987) and a Biosphere Reserve in 1989 is located in the Ganges, Brahmaputra, Meghna (GBM) in Bangladesh and West Bengal (India) coast with an area 16,902 km². Sundarbans' green cover has been standing firm against natural disasters for ages (Chand 2012). The vegetation consists of 64 plant species (UNEP-WCMC-2008) and they have the capacity to withstand estuarine conditions and saline inundation on account of tidal effects, can face strong winds. Sundari (*Heritiera fomes*), Gewa (*Excoecaria agallocha*), Kankra (*Bruguiera gymnorhiza*), Passur (*Xylocarpus mekongensis*), *Rhizophora* spp., Sundari (*Heritiera fomes*), Goran (*Ceriops decandra*) and Baen (*Avicennia alba*) etc., are important. The Sundarbans mangrove forests with triple tier natural protection mechanisms protect the inlands from cyclonic storms originated in the Bay of Bengal. Most of the plant species have special physical and physiological adaptation to protect themselves as well as these prevent the mounting wind pressure of the cyclones, and storm surges. Viviparous germination, pneumatophore, stilt roots, buttresses, floating behavior of drupes and pods etc., are the unique natural adaptation features of many mangrove species (Morton 1988). Some trees e.g. Baen and Sundri are so strong that they can easily resist 11,100 psi load (Sattar et al 1987). Tornado-prone zone areas have specially adapted growing bamboo clumps which are extremely strong with high elasticity and can easily disband the tornadoes. Therefore, every homestead has have bamboo clumps in the west and or north-west sides (Rahman 2004). Bamboos also protect erosion with their strong anchorage-fibrous root system; similarly many palms and nuts also break the wind speed and protect the habitats and the lives from disasters especially, the cyclones and erosion (Rahman 2013b). Local communities developed many adaptation techniques, innovations and knowledge to address climatic vulnerability. Rural people, farmers and other developed their location specific knowledge and practices of agriculture, natural resource management, human and animal health care. They know far more about their environment, livelihoods and how their society functions than those from the outside (BARCIK 2013).

The inhabitants of the coastal zone used to adapt and manage the frequent storms and cyclones using their wisdoms usually building their homes on raised floor, low height and surrounded by highly protective windbreaks with coconut, areca nut and fishtail palm etc. (Fig 40).



Fig.40 Homes with windbreaks of the coastal zone

Hill forests of the eastern and northern region and the central Sal forests are the natural defense system used to protect the human habitats from storms and tornadoes, erosion and land-sliding. Traditionally, the homes of the 1960's or before, the people used to choose the multipurpose tree and shrubby plants those are specially established thinking to serve the specific purpose e.g. wind protection, erosion control and habitat restoration and of course for health conscious drinks and foods (Rahman 2004). Maintaining their appropriate spacing, coconut, areca nut, dates, Palmyra palm, fish-tail palm, Cyperus, and Screw pine etc., are suitable for crop production, as well as, natural protection of the shelter home from the adverse condition. Palms can withstand 350 km/hour wind speed and their specially designed highly elastic leaves can break the wind speed. These plants altogether provide a triple-tier protection measure against tidal surges and strong winds (Rahman 2012).

The houses of the coastal zone are usually made on wooden platforms on raised earth excavating two or three ponds in each and every home. The flood plains were nicely conserved by digging deep ponds for multipurpose uses. Excavated earth used to meet the purpose of house building on raised landscape and the houses were designed to face the south. Large ponds with an area above 1 acre are termed as Dighi; above 10 acres is Sagor and smaller ponds of area less than an acre are called as Pukur.

The houses of the coastal hilly areas of Chittagong and Chittagong Hill Tracts are traditionally designed with a central king post with suspended roof to protect from the earthquakes. Still in Chittagong and Cox,s Bazar, there are Khyangs, the Buddhist temples with traditional king posts. There are other traditional practices e.g. rainwater harvesting and storage in large earthen vats for domestic usages, this practice is a very common one for the coastal island-dwellers (Rahman 2012). Among the other traditional practices, people of the coastal zone used to do their marketing in the Haats and Bazars during the daytime using natural lights and to avoid the transportation problems at night.

The traditional adaptation practices have been documented herein and their scientific evaluation requires in-depth field level studies to generate the knowledge and promote the more resilient practices to benefit the coastal community.

VIII. Traditional Landscaping for Homes in the Floodplains:

Typically, rural homesteads follow a courtyard layout. The basic features are: a group of separate structures surround an open space which is defined as the courtyard. Each structure is essentially a one-roomed accommodating different function such as dwelling units for extended family members, kitchens and granaries. Toilets and outhouses such as cowsheds are located on the periphery of the homestead and where recycling of biomass takes place. The layout is introverted, that is, the buildings face away from the outside and are accessed through the courtyard. Entry into the compound from the outside is through gaps between structures. The homestead is extensively planted with trees along the boundary which strengthens the introverted layout. In flood-prone areas, an indigenous practice is to build homesteads on a raised mound, built with earth from the excavation of canals and ponds. Presently, because of resource constraints, it is not always possible for people to raise homesteads adequately above flood level. Planting design and selection of trees is the main aspect of landscaping. Land selection, preparation and homesteads are also part of landscaping. Homestead cropping maintains special adaptation procedure for raising creeper and climber crops on raised mound made with earth boulders to prevent water-logging in the wet monsoon. This is a scientific process to break the capillary system by the air-spaces among the earth-boulders (Rahman 2004, ADPC 2005).

Among the other traditional adaptation practices, the season-based cropping to maintain the flora and fauna of soils of dry and wet phases; floating agriculture and deepwater rice cultivation are also important. People used to aware of getting the indication of storms and winds watching the mouth of the nests of the weaving birds (Randy Pepler 2010).

IX. Coastal Cities

Most of the coastal cities in Bangladesh are situated on the riverbanks of low-lying tidal zones at an average elevation of 1.0–1.5 m from the sea level. Construction and management of buildings, roads, power and telecommunication transmission lines, drainage and sewerage and waste management are mostly mismanaged and vulnerable to climate change disasters. Cyclonic storms associated with tidal floods impact seriously the infrastructures and thus the livelihoods. Although coastal cities are the ultimate shelters of the coastal people during the extremes events, the coastal cities are not safe and cannot support them due to poor infrastructure.

X. Coastal City Governance

Weak local governance and municipal management coupled with high poverty incidence, and remote locations, create persistent development challenges to these areas. Poor coordination between City Development Authority and the Ministry of Housing and Public Works, and high dependency on the central government are the important causes of hindrance in infrastructure development of the coastal cities. Climate change, climate variability, and natural disasters further aggravate development in coastal towns, with a disproportionate impact on women and the poor. Local level initiative for planning is mostly missing with top down governance and very limited participation of the stakeholders. Such low participation makes the city planning unrelated to the needs of the stakeholders on the one hand and that of reflection of ground realities on the other.

XI. Policy Priorities

Defense Mechanism: Triple-tier defense mechanism of Sundarban mangrove reduces sea current and tidal surges by the lower storey, middle storey resists strong wind and the higher storey breaks the strong wind. However, continuous destruction of these through pen shrimp culture has increased intensity of cyclonic and tidal surges as observed in cyclone SIDR and AILA. Formulation of a standing policy on pen shrimp culture (gher) could help in preserving and restoring mangrove ecosystem.

Coastal Cities: Coastal cities are very important to coastal people as these provide basic shelters to them during climate extremes. Analysis of development of coastal cities involving buildings, roads, power and telecommunication, transmission lines, drainage and sewerage etc point to climate change impacts increase such as long term water logging, sea level rise leading to tidal surges, cyclones, flood, erosion etc. An integrated urban coastal policy for rainwater harvesting, reuse of surface and grey water in the urban cities could help in reducing impact of climate extremes.

Involvement of Stakeholders: Bangladesh government has already taken a few steps towards infrastructure development. But it has been observed that the government policies concerning coastal communities are often not rooted in ground realities and too remote to be accessible. An integrated coastal policy involving the areas of sanitation, arsenic, road transportation, power, water-logging, salinity, land-sliding and erosion could contribute to development of smart coastal cities.

XII. Conclusions

Drought is one of the most important natural and climate induced disasters affecting millions almost every year in the LDCs including Bangladesh. Mitigation and adaptation measures can reduce drought vulnerability through appropriate policy intervention and community participation.

Marine environment of the BoB is changing in terms of rise in sea water temperature, salinity and sea level, pH of the sea water, changes in the current, upwelling, water mass movement and anthropogenic activities affecting the marine lives, coastal zone as well as infrastructure. Over 400 million people in the BoB are dependent on marine and coastal resources for food and livelihood. Environmental changes, anthropogenic activity, high dependency, over exploitation etc. have degraded the ecological phenomena which need to be balanced through corrective actions.

Flood is one of the pervasive natural and climate induced phenomena causing millions to suffer in almost every year in Bangladesh and Nepal. Historical data shows that the scale, intensity and duration of floods have increased in Bangladesh with adverse consequences. National Adaptation Program (NAPA) has prioritized flood as the most challenging disaster which affects 80% of the land area. Both the countries initiated administrative measures for flood mitigation while the communities use traditional knowledge for adaptation to floods.

Analysis of Coastal Zone Management (CZM) practices in Bangladesh involving establishment of windbreak without pacing for wind flow, gher (pen culture) for shrimp cultivation replacing mangroves, polderization etc. has adversely affected natural systems (natural forest hills, Sundarban trees) that reduce impact of cyclones and tornadoes as well as wetlands and reduce impact of floods, droughts in the coast. Establishing an integrated CZM policy with adequate attention to natural systems and scientific connotation of these systems could help in mitigation of impacts of natural disasters in the coast.

It is evident from the synthesis that global environmental changes are affecting sustainable development worldwide with worst impacts on the LDCs. Findings of a synthesis work on the Global Environment Change and Sustainable Development: Needs of the Least Developed Countries support this conclusion and presents the reasons of environmental changes, adaption mechanisms as well as policy options for sustainable development of Asian LDCs and SIDs. The findings of the synthesis indicate that most of the environmental changes are induced by human activities leading to changes in the marine ecosystems and costal zones as well as changing the patterns, intensity and frequency of natural

disasters like floods and droughts that are affecting sustainable development in Asian LDCs and SIDSs. The susceptible human-nature interactions has established a firm relation between environmental change and natural disaster where each giving the other intensity and perpetuity. In most of the cases, the countries of investigations are found to cope with the environmental changes and induced natural disasters using indigenous knowledge as well as natural and traditional practices.

XIII. Future Directions

This project has documented very important aspects like traditional deep water reservoirs, natural and traditional defense mechanism, triple-tier defense of mangroves, which are very essential for long-term solution of disasters like flood, marine and coastal ecology, tidal surges and cyclones etc. These outcomes open up opportunity for new study to assess long term options for mitigation as well as adaptation to climate extremes. Importance of plantation with right plant at right place according to their habitats and habit will also open the door of sustainable living and resource management. Scientific validation and consequent institutionalization as well as awareness building of the indigenous and traditional knowledge and practices identified could be the policy options for community based sustainable development in many LDCs including SIDS.

References

- A. Ali, (1996). Vulnerability of Bangladesh to climate change and sea level rise through tropical cyclones and storm surges. *Water Air Soil Pollut* 94(d):171–179.
- A. C. Basak. 1994. Wilting of sissoo (*Dalbergia sissoo* Roxb.) in strip plantations in Bangladesh. *Bangladesh Journal of Forest Science* 23 (1): 67-68.
- A. C. Basak. 2006. Mortality of Sissoo (*Dalbergia sissoo* Roxb.) in Bangladesh and its Management (PhD Thesis). Jahangirnagar University, Savar, Dhaka. 240 pp.
- A. C. Basak. 2013. Death of century-old Albizia saman and some exotic trees in Chittagong (Unpublished).
- A. Dai, (2011). Drought under global warming: A Review. *Wiley Interdisciplinary Reviews ; Climate Change*, 2(1), 45-65
- A. Dixit, M. Upadhya, K. Dixit, A. Pokhrel, D.R. Rai, 2009: Living with water stress in the hills of the Koshi Basin, Nepal. Kathmandu: ICIMOD. pp. 5.
- A. Dixit, M. Upadhya, A. Pokhrel, K.M. Dixit, D.R. Rai, and M. Devkota, 2007: Flood Disaster Impacts and Responses in Nepal Tarai's Marginalised Basins, In *Working with the Winds of Change, Toward Strategies for Responding to the Risks Associated with Climate Change and other Hazards*, Moench, M. and Dixit, A. (eds.), Chapter 6, pp. 119-158, Pro-Vention Consortium, Institute for Social and Environmental Transition-International and Institute for Social and Environmental Transition-Nepal.
- A. F. M. Saleh, M. A. Mazid and S. I. Bhuiyan, (2000). Agrohydrologic and drought-risk analyses of rainfed cultivation in northwest Bangladesh. In T. P. Tuong, S.P. Kam, L.J. Wade and S. Pandey
- A. Firoze, The southwest coastal region: problems and potentials. Dhaka, The DailyStar, XIV, Issue 215 (2003).
- A. Firoze, The southwest coastal region: problems and potentials. Dhaka, The DailyStar, XIV, Issue 215 (2003).
- A. K. Jha, R. Bloch, J. Lamond, (2012) *A Guide to Integrated Urban Flood Risk Management for the 21st Century*, 2012.
- A. Mascarenhas, Extreme events, intrinsic landforms and humankind: post-tsunami scenario along Nagore-Velankanni Coast, Tamilnadu. *Current Science*, 90: (2006) 1195–1201.
- A. Mascarenhas, Extreme events, intrinsic landforms and humankind: post-tsunami scenario along Nagore-Velankanni Coast, Tamilnadu. *Current Science*, 90: (2006) 1195–1201.
- A. R. Sena Gomes and T. T. Kozlowski. 1980c. Effects of flooding on growth of *Eucalyptus camaldulensis* and *E. globulus* seedlings. *Oecologia* 46:139-142.
- A. U. Ahmed, (2004). *Adaptation to climate change in Bangladesh: learning by doing*. UNFCCC Workshop on Adaptation, Bonn, 18 June 2004.
- A.A. Baky, A.M. Zaman, and A.U. Khan, (2012) *Managing Flood Flows for Crop Production Risk Management with Hydraulic and GIS Modeling: Case Study of Agriculture Areas in Shariatpur*: SAARC Workshop on Flood Risk Management in South Asia. 2012
- A. Ahmed, 2012. *Women's Adjustment with Flood in Ganges Dependent Area of Bangladesh*
- A. Banica; J. Bastard, and M. Kosiek, *Integrated Coastal Zone Management (ICZM): a framework to tackle environmental issues? Danish Approach* Centre for Environmental Studies, June 2003 Reprocenteret, Det Naturvidenskabelige Fakultet, Aarhus Universitet, (2003) ISBN: 87-7785-146-3
- A. Banica; J. Bastard, and M. Kosiek, *Integrated Coastal Zone Management (ICZM): a framework to tackle environmental issues? Danish Approach* Centre for Environmental Studies, June 2003 Reprocenteret, Det Naturvidenskabelige Fakultet, Aarhus Universitet, (2003) ISBN: 87-7785-146-3
- A.K. Deb, Fake blue revolution: environmental and socio-economic impacts of shrimp culture in the coastal areas of Bangladesh. *Ocean & Coastal Management*, 41: (1998) 63–88.
- A.K. Deb, Fake blue revolution: environmental and socio-economic impacts of shrimp culture in the coastal areas of Bangladesh. *Ocean & Coastal Management*, 41: (1998) 63–88.
- A.K.E. Haque, Sanitary and phyto-sanitary barriers to trade and its impact on the environment: the case of shrimp farming in Bangladesh. Dhaka, IUCN Bangladesh, Country Office, (2004) 63 pp.
- A.K.E. Haque, Sanitary and phyto-sanitary barriers to trade and its impact on the environment: the case of shrimp farming in Bangladesh. Dhaka, IUCN Bangladesh, Country Office, (2004) 63 pp.
- A.M.R. Chowdhury, 1988, The 1987 flood in Bangladesh: an estimate of damage in twelve villages. *Disasters*, v. 12(4), p. 294-300.

- A.Nishat, M.Reazuddin, R. Amin, and A.R. Khan, (Eds). (2000). The 1998 flood: impact on the environment of Dhaka city. Department of Environment and IUCN Bangladesh, Dhaka.
- AA Alabsi (2001). Country Pasture/Forage Resource Profiles
Yemen:<http://www.fao.org/ag/AGP/AGPC/doc/counprof/Yemen/yemen.htm>
- Ackerson, In Eucalyptus Enduring Myths, Stunning Realities Abbasi, SA. Ramenh, N. and Vinithan, S. 2004;
Discovery Publishing House 4831/24, Ansari road, New delhi, 110002, India ISBN W8171418929, (1980) pp 26-27
- Ackerson, In Eucalyptus Enduring Myths, Stunning Realities Abbasi, SA. Ramenh, N. and Vinithan, S. 2004;
Discovery Publishing House 4831/24, Ansari road, New delhi, 110002, India ISBN W8171418929, (1980) pp 26-27
- Albert, S.,etal., 2012. Building Social and Ecological Resilience to Climate Change in Roviana, Solomon Islands. The University of Queensland, Brisbane, pp. 1–274.
- Ali, A., Chowdhury, J.U., 1997. Tropical cyclone risk assessment with special reference to Bangladesh. MAUSAM (formerly Indian Journal of Meteorology Hydrology and Geophysics) 48, 305–322
- AON Benfield, May 2013 Global Catastrophe Recap (2013)
http://thoughtleadership.aonbenfield.com/Documents/20130604_if_may_global_recap.pdf
- AON Benfield, May 2013 Global Catastrophe Recap (2013)
http://thoughtleadership.aonbenfield.com/Documents/20130604_if_may_global_recap.pdf
- APDC, Handbook on Design and Construction of Housing for Flood-prone Rural Areas of Bangladesh ISBN: 984-32-2163-X (2005): Printed by Nymphaea, 67/D, Panthapath, Dhaka-1209, Bangladesh;
http://www.adpc.net/audmp/library/housinghandbook/handbook_complete-b.pdf
- APDC, Handbook on Design and Construction of Housing for Flood-prone Rural Areas of Bangladesh ISBN: 984-32-2163-X (2005): Printed by Nymphaea, 67/D, Panthapath, Dhaka-1209, Bangladesh;
http://www.adpc.net/audmp/library/housinghandbook/handbook_complete-b.pdf
- ARCS (2007) Drought Monitoring Using Vegetation and LST Indices in Nepal and Northeastern India <http://www.a-a-r-s.org/acrs/proceeding/ACRS2007/Papers/PS2.G5.4.pdf> accessed on 4.8.2013
- AW Akonda, 'Bangladesh' in DA Scott ed, A Directory of Asian Wetlands, IUCN, Switzerland, (1989).
http://www.banglapedia.org/HT/W_0051.HTM accessed on 16th September 2013
- AW Akonda, 'Bangladesh' in DA Scott ed, A Directory of Asian Wetlands, IUCN, Switzerland, (1989).
http://www.banglapedia.org/HT/W_0051.HTM accessed on 16th September 2013
- Aziz Ahmad, H.B., Luqueman, A., Atapattu, A., Chullasorn, S., et al, 1998. Regional stewardship for sustainable marine resources management in the Bay of Bengal. In: K. Sherman, E. Okemwa and M. Ntiba (eds), "Large Marine Ecosystems of the Indian Ocan: Assessment, Sustainability, and Management." Blackwell Science. ISBN: 0632043180
- B. K. Bakshi. 1954. Wilt of Shisham (*Dalbergia sissoo* Roxb.) due to *Fusarium solani* sensu Snyder and Hansen. *Nature* 174 (4423): 278-291.
- B. K. Bakshi. 1957. Wilt disease of Shisham (*Dalbergia sissoo* Roxb.) IV. The effect of soil moisture on the growth and survival of *Fusarium solani* in the laboratory. *Indian Forester* 83 (8): 505-511.
- B. K. Paul, (1998). Coping mechanisms practiced by drought victims (1994/5) in North Bengal, Bangladesh. *Appl Geogr* 18(4): 355–373.
- B.K. Paul, (1995). "Flood Research in Bangladesh: Major Findings and Future Research Direction." A paper presented at the 1995 Annual Meeting of the Association of American Geographers held in Chicago, IL, March 14-18, 1995.
- B.K. Paul, Farmers' and Public Responses to the 1994-95 Drought in Bangladesh: A Case Study, Quick Response Report # 76 Department of Geography, Dickens Hall, Kansas State University, Manhattan, KS 66506 : (1995)
- Bakshi, B. K.; Arora, K. K. and Sujan Singh. 1959. Root diseases of Shisham (*Dalbergia sissoo* Roxb.). VII. Physiological studies on the wilt organism, *Fusarium solani*. *Indian Forester* 85 (5): 310-313.
- Bangladesh Forest Department. 2011. Homepage, Bangladesh Forest Department.
- Bangladesh National Herbarium, Red Data Book of Vascular Plants Bangladesh, Eds. M.S. Khan, M.M Rahman and M.A Ali., Bangladesh National Herbarium, (2001) ISBN 984-32-0128-0

- Bangladesh National Herbarium, Red Data Book of Vascular Plants Bangladesh, Eds. M.S. Khan, M.M Rahman and M.A Ali., Bangladesh National Herbarium, (2001) ISBN 984-32-0128-0
- Banglapedia. 2006. Website: www.banglapedia.org
- Bayliss-Smith, T., et al., 2010. Managing Ontong Java: social institutions for production and governance of atoll resources in Solomon Islands. *Singap. J. Trop. Geogr.* 31(1),55–69.
- BBC News October 6, 2011
- BBS 1994 BBS (Bangladesh Bureau of Statistics). 1994. 1993 Statistical Yearbook of Bangladesh. Dhaka.
- BBS. 1986. The Bangladesh Census of Agriculture and Livestock: 1983-84: Structure of Agricultural Holdings and Livestock Population. Dhaka.
- BDNews 2006: Prolonged drought throws tea industry into deep crisis <http://dev-bd.bdnews24.com/details.php?id=31529&cid=2>
- BH Walker, RH Emslie, RN Owen-Smith, RJ Scholes (1987) To cull or not to cull: Lessons from a southern African drought *J Appl Ecol* 24: 381-401
- Biesbroek, G.R., et al., 2013. On the nature of barriers to climate change adaptation. *Reg. Environ. Change* 13(5),1119–1129.
- Bird, E.C.F., 1979: Environmental problems related to the coastal dynamics of humid tropical deltas; Proceedings of the Jakarta workshop on coastal resources management <http://www.unu.edu/unupress/unupbooks/80130e/80130E04.htm#>
- BoM (2013), 'Living with drought', Bureau of Meteorology, Canberra, available at www.bom.gov.au/climate/drought/livedrought.shtml, accessed October 2013.
- Brammer, H. (1987). Drought in Bangladesh: Lessons for Planners and Administrators. *Disasters* 11(1): (1995) 21-29
- Brown et. al., In *Eucalyptus Enduring Myths, Stunning Realities* Abbasi SA., Ramesh, N. and Vinithan, S. 2004; Discovery Publishing House 4831/24, Ansari road, New delhi, 110002, India ISBN W8171418929, (1976) pp 26-27
- Brown et. al., In *Eucalyptus Enduring Myths, Stunning Realities* Abbasi SA., Ramesh, N. and Vinithan, S. 2004; Discovery Publishing House 4831/24, Ansari road, New delhi, 110002, India ISBN W8171418929, (1976) pp 26-27
- BS Kanvazina (1981) Nyala culling and capture report; Langwe National Park. Department of National Parks and Wild life, Lilongwe
- C. Bhuiyan, R.P. Singh, and F.N. Kogan, (2006): Monitoring drought dynamics in the Aravalli Region (India) using different indices based on ground and remote sensing data, *International J. Applied Earth Observation and Geo-information* 8(4), 289-302
- C.Ninno C, Dorosh PA, Smith LC, Roy DK (2001). The 1998 floods in Bangladesh: disaster impacts, household coping strategies, and response.
- CEGIS Study Report 2013 Vulnerability to Climate Induced Drought Scenario and Impacts <http://203.83.183.19/bitstream/handle/123456789/15/142.%20Vulnerability%20to%20Climate%20Induced%20Drought%20SCENARIO%20AND%20IMPACTS.pdf?sequence=3> accessed on 9 May 2014
- Centre for Low Carbon Future (2012) Food Security: Near future projections of the impact of drought in Asia
- CHD Magadza (1994): Climate Change ; some likely multiple impacts in southern Africa. *Food Policy* 19(2); 165-191
- Choudhury A.M. [et al.] (2003). Climate Change and its Impacts on Water Resources of Bangladesh [Book Section] *Climate Change and Water resources in South Asia: Proceedings of year End Workshop / book auth. Muhammad A. - Kathmandu . In CEGIS Study Report 2013 Vulnerability to Climate Induced Drought Scenario and Impacts* <http://203.83.183.19/bitstream/handle/123456789/15/142.%20Vulnerability%20to%20Climate%20Induced%20Drought%20SCENARIO%20AND%20IMPACTS.pdf?sequence=3> accessed on 9 May 2014
- Climate Change Cell, Impact Assessment of Climate Change and sea Level Rise on Monsoon Flooding (2009) http://www.climatechange.org.bd/publications/ResearchDocs/Monsoon_Flooding.pdf accessed on 15th April 2013
- Climate Change Cell, Impact Assessment of Climate Change and sea Level Rise on Monsoon Flooding (2009) http://www.climatechange.org.bd/publications/ResearchDocs/Monsoon_Flooding.pdf accessed on 15th April 2013
- Climate Change Cell, Govt. of Bangladesh (2006): Climate Variability and Change in Bangladesh Impacts, Vulnerability and Risks <http://www.climatechange.org.bd/publications/07factsheetEnglish.pdf>

- Coastal Zone Policy, Ministry of Water Resources; Government of the People's Republic of Bangladesh (2005)
http://www.warpo.gov.bd/pdf/czpo_eng.pdf
- Coastal Zone Policy, Ministry of Water Resources; Government of the People's Republic of Bangladesh (2005)
http://www.warpo.gov.bd/pdf/czpo_eng.pdf
- D. Alexander, (1995). Changing perspectives on natural hazards in Bangladesh; *Natural Hazards Obs* 10(1):1–2.
- D. Kumar, In *Eucalyptus Enduring Myths, Stunning Realities* Abbasi SA, Ramesh N and Vinithan S. 2004; Discovery Publishing House 4831/24, Ansari road, New delhi, 110002, India ISBN W8171418929, (1984) pp 26-27
- D. Kumar, In *Eucalyptus Enduring Myths, Stunning Realities* Abbasi SA, Ramesh N and Vinithan S. 2004; Discovery Publishing House 4831/24, Ansari road, New delhi, 110002, India ISBN W8171418929, (1984) pp 26-27
- D. Michel and A. Pandya, *Coastal Zones and Climate Change; Stimson's Regional Voices*, ISBN: 978-0-9821935-5-6 (2010) www.stimson.org/programs/regional-voices
- D. Michel and A. Pandya, *Coastal Zones and Climate Change; Stimson's Regional Voices*, ISBN: 978-0-9821935-5-6 (2010) www.stimson.org/programs/regional-voices
- D. Prain. 1903. *Bengal Plants*. Vol. 1 & 2, Indian reprint (1963), Botanical Survey of India, Calcutta, India.
- DA Widawasky, and JC O'Toole, (1990): *Prioritizing the rice biotechnology research agenda for Eastern India*. Rockefeller Foundation Press, New York, NY, 86 pp
- Das, S. 1977: *Taxonomy of calanoid copepods of the Karnafuli estuary*. A postgraduate dissertation. Institute of Marine Sciences, University of Chittagong, Bangladesh 25p.
- DOF (Department of Fisheries), 20 08. *Fisheries Resources Development Campaign (2008)*. Directorate of Fisheries, Dhaka 95 p.
- Dube O. P. and Sivakumar, M. V. K., 2015. *Global environmental change and vulnerability of Least Developed Countries to extreme events*. Special Issues. SI: IGBP APN. Volume 7 (2015).
- E. L. Webb and S. M. Y. Hossain. 2005. *Dalbergia sissoo mortality in Bangladesh plantations: correlations with environment and management parameters*. *Forest Ecology and Management* 206 (1-3):61-69.
- E.C.F. Bird, *Environmental problems related to the coastal dynamics of humid tropical deltas; Proceedings of the Jakarta workshop on coastal resources management, (1979)*
<http://www.unu.edu/unupress/unupbooks/80130e/80130E04.htm#>
- E.C.F. Bird, *Environmental problems related to the coastal dynamics of humid tropical deltas; Proceedings of the Jakarta workshop on coastal resources management, (1979)*
<http://www.unu.edu/unupress/unupbooks/80130e/80130E04.htm#>
- Ekström, M., et al., 2013. *Examination of climate risk using a modified uncertainty matrix frame work—applications in the water sector*. *Glob. Environ. L Change* 23(1),115–129.
- Enemark, S. 2007: *Coastal Areas and Land Administration – Building the Capacity; Strategic Integration of Surveying Services, 6th FIG Regional Conference 2007, San José, Costa Rica 12-15 November 2007*
- European Commission (2007) *Water scarcity and droughts in-depth assessment, second interim report events, and their implications for sustainable development*. Technical paper. FCCC/TP/2008/3 20 November 2008.Pp57
- FAO 2008: *Climate Change and Food Security: A Framework Document*, Food and Agriculture Organization of the United Nations Rome, 2008; <http://www.fao.org/forestry/15538-079b31d45081fe9c3dbc6ff34de4807e4.pdf> accessed on 22 August 2013.
- Food and Agricultural Organization. 2011. *State of the world's forests*, Food and Agriculture Organization of the United Nations, Rome.
- Ford, J.D., Berrang-Ford, L., Paterson, J., 2011. *A systematic review of observed climate change adaptation in developed nations*. *Clim. Change* 106(2),327–336 (Available at: (<http://www.springerlink.com/index/10.1007/s10584-011-00455>) (accessed 13.07. 11).
- ftp://wxmaps.org/pub/kinter/Projects/monsoon/Indian_monsoon_chapter.pdf
- G.C. Hargel et al (2007), *Detection of human influence on a new 1500yr Climate Reconstruction*. *J. Clim.*, 20, 650-666 <http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter9.pdf>
- Gaillard, J.C., 2012. *The climate gap*. *Clim. Dev.* 4(4),261–264.
- GDIS, *Global Drought Information System (2013)* (<http://www.drought.gov/gdm/current-conditions>)
- GFDRR 2011: 2011 – Lao PDR – Typhoon: JDLNA Undertaken as a Response to Severe Flooding after Typhoon Haima <https://www.gfdr.org/node/1018>

- Gopal, B and Chouhan, M, 2006: Biodiversity and its conservation in the Sundarban Mangrove Ecosystem : Aquatic Sciences - Research Across Boundaries, Volume 68, Number 3 (2006), 338-354, DOI: 10.1007/s00027-006-0868-8 <http://www.springerlink.com/content/m4647726hx707v08/>
- GoS, 2005. National adaptation Q9 programme of action, Samoa, Apia, Samoa, Ministry of Natural Resources. Environ. Meteorol., 1–66.
- H. Brammer, (1987). Drought in Bangladesh: Lessons for Planners and Administrators. Disasters 11(1):21-29
- H. Brammer, 1989, Monitoring the evidence of the greenhouse effects and its impacts on Bangladesh. In Moudud, H. (ed.) Proceedings of the Conference on the Greenhouse Effects and Coastal Area of Bangladesh. http://en.wikipedia.org/wiki/2010_Pakistan_floods
- http://en.wikipedia.org/wiki/2013_North_India_floods
- http://en.wikipedia.org/wiki/Floods_in_the_United_States:_2001%E2%80%93present.
- <http://en.wikipedia.org/wiki/Ramsagar>
- <http://www.aseanbiodiversity.info/Abstract/51004215.pdf> accessed on 17 August 2013.
- <http://www.camclimate.org.kh>
- <http://www.iubat.edu/kbad/>
- <http://www.slideshare.net/globalwaterpartnership/integrated-drought-management-in-south-asiaa-regional-proposal-by>
- <http://www.theguardian.com/environment/2015/jul/27/only-100-tigers-left-in-bangladesh>
- Huffington Post (2011) Afghanistan Faces Drought, Hunger (http://www.huffingtonpost.com/2011/12/03/afghanistan-drought_n_1127029.html accessed in October 2013).
- Hussain, M.G., M.E. Hoq, (Eds.), 2010. Sustainable Management of Fisheries Resources of the Bay of Bengal—Compilation of National and Regional Workshop Reports. Support to Sustainable Management of the BOBLME Project, Bangladesh Fisheries Research Institute. SBOBLMEP Pub./Rep. 2122 p.
- I Cook Benjamin et al (2012) Pan-continental droughts in North America over the last Millennium, NASA Goddard Institute for Space Studies, 2880 Broadway, New York, NY 10025
- IFRC (2011) Drought in the Horn of Africa: Preventing the next disaster, International Federation of Red Cross and Red Crescent Societies, Geneva
- International Food Policy Research Institute Research Report. Washington, DC.
- IPCC- 2001. Climate change 2001—Impacts, adaptation and vulnerability: Contribution of Working Group II to the Third Assessment Report, Cambridge University Press, 1032 pp.
- IPCC Special Report 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change (IPCC)- (2012), IPCC Working Group II. Cambridge University Press: ISBN 978-1-107-025006-6, www.cambridge.org/978117607804
- IPCC-2007, Oceans and Coastal Zones Climate Change: Working Group II: Impacts, Adaptation and Vulnerability (2007). http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch10s10-2-4-3.html
- IPCC-2007, Oceans and Coastal Zones Climate Change: Working Group II: Impacts, Adaptation and Vulnerability (2007). http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch10s10-2-4-3.html
- IRIN 2011: Afghan drought conditions could spell disaster <http://www.irinnews.org/report/93781/analysis-afghan-drought-conditions-could-spell-disaster>
- IRIN-2008. YEMEN: Drought displaces thousands in mountainous northwest <http://www.irinnews.org/report/78048/yemen-drought-displaces-thousands-in-mountainous-northwes>
- Islam, M.S. 2003. Perspectives of the coastal and marine fisheries of the Bay of Bengal, Bangladesh. Ocean & Coastal Management, 46: 763–796.
- IWMI Research Report 133), ISSN 1026-0862, ISBN 978-92-9090-711-4
- J. H. Christensen, B. Hewitson, A. Busuioac, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W. T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C. G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton, (2007). Regional climate projections. In S. D. Solomon, M. Qin, Z. Manning, M. Chen, K. B. Marquis and M.T. Averyt, N.J. Erickson, Q.K. Ahmad, and A.R. Chowdhury, (1993). Socio- Economic Implications of Climate Change for Bangladesh; Dhaka: Bangladesh Unnayan Parishad.

- J. Kreuzwieser, S. Furnis and H. Rennenbery. 2002. Impact of water-logging on the N-metabolism of flood-tolerant and non-tolerant tree species. *Plant, Cell and Environment* 25 (8):1039-1049.
- J. L. Nayava, (1974): Heavy monsoon rainfall in Nepal, *Weather, Roy. Met. Soci., U. K.*, 29: 443-450.
- Joint Assessment Report (2009): 2008/09 Winter Drought in Nepal Crop and Food Security Assessment; Mistry of Agriculture and Cooperatives of Nepal, WFP and FAO
http://reliefweb.int/sites/reliefweb.int/files/resources/098625C201A159E2492575C8001A1A0C-Full_Report.pdf accessed on 14 August 2013
- K. A. S. Murshid, (1987). *Weather, New Technology and Instability in Foodgrain Production in Bangladesh*. The Bangladesh Development Studies 15(1):31-56.
- K. B. S. Rasheed, (1998). Status of land resource use and desertification, drought and land degradation in Bangladesh: obstacles and effective policy options and measures for sustainable use of land resources. In: Proceedings of the national awareness seminar on combating land degradation/desertification in Bangladesh, April 1998, Dhaka.
- K. D. Larson, B. Schaffer and F.S. Davies. 1989. Flooding, leaf gas exchange and growth of mango in containers. *J. Am. Soc. Hortic. Sci.* 116:156-160.
- K. Weisman, and R.P. Chhetri 920110 Governance of climate Change Adaptation Finance in Nepal: Country Brief, Oxfam International, Review of Climate Change Adaptation Practices in South Asia, Oxfam Research Report, November 2011.
- K.E. Trenberth; P.D. Jones; P. Ambenje; R. Bojariu, D. Easterling; A. Klein Tank; D. Parker, F. Rahimzadeh, J.A. Renwick; M. Rusticucci; B. Solden, and P. Zhai, (2007): Observations: Surface and atmospheric Climate Change. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group/to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press, Cambridge, UK and New York, NY, pp 235-336
- K.O. Emery and D.G. Aubrey. 1989: The Ganges of India, *Journal of Coastal Research* Vol. 5.3, pp. 489-501.
- Kaushik, J. C.; Ajit Singh, Singh, A. and Nair, K. S. S. 1993. Effect of soil texture and moisture on seedling root rot of *D. sissoo* and its control. In: Sharma, J. K. and Varma, R. V. (eds.). *Impact of diseases and insect pests in tropical forests*. Proceedings of the IUFRO Symposium, Peechi, Kerala, India. 23-26 Nov. 1993. pp. 209-216.
- Khan, G., (2002). *Aquatic Resources Development, Management and Conservation Studies: Fry Collection Action Plan Draft— PL Fishery Management and Conservation*. DoF/GEF/World Bank. 69 p.
- Kuruppu, N., 2009. Adapting water resources to climate change in Kiribati: the importance of cultural values and meanings. *Environ. Sci. Policy* 12(7),799–809.
- Lhakapa (2012) A Religious tradition of calling rain: A study in the village of Baepam, Udzorong Gewog in Trashigang District of Bhutan, *The Research Journal of Sherubtse College*, Vol. 12 No.1 2012
- M Salar Khan et al ed, *Wetlands of Bangladesh*, Bangladesh Centre for Advanced Studies, Dhaka, (1994).
http://www.banglapedia.org/HT/W_0051.HTM accessed on 16th September 2013
- M Salar Khan et al ed, *Wetlands of Bangladesh*, Bangladesh Centre for Advanced Studies, Dhaka, (1994).
http://www.banglapedia.org/HT/W_0051.HTM accessed on 16th September 2013
- M. A. Jabbar, M. U. Chaudhury and M. H. Q. Huda, (1982), Causes and effects of increasing aridity in Northwest Bangladesh. In the Proceedings of first thematic conference on remote sensing of arid and semi-arid lands, Cairo, Egypt, January 1982.
- M. A. Mazid, M. A. Mortimer, C. R. Riches, A. Orr, B. Karmaker, A. Ali, M. A. Jabbar, And L. J. Wade, (2005). Rice establishment in drought-prone areas of Bangladesh. In K. Toriyama, K. L. Heong and B. Hardy, (eds) *Rice is life: scientific perspectives for the 21st century*. International Rice Research Institute, Manila, Philippines.
- M. A. Miyan, (2012) Vulnerabilities of the People of Bangladesh to Disaster: Regional Consultative Meeting on “Engaging SAARC for Disaster Resilience” Islamabad Pakistan November 1-2, 2012
- M. A. Miyan, (2012) Vulnerabilities of the People of Bangladesh to Disaster: Regional Consultative Meeting on “Engaging SAARC for Disaster Resilience” Islamabad Pakistan November 1-2, 2012
- M. A. Rahman 2011. Opportunities for Permaculture in the Rural Homes of Bangladesh.
<http://feppcar.org/158/opportunities-for-permaculture-in-the-rural-homes-of-bangladesh/#more-158>
- M. A. Rahman, 2004. *Plantation Crops and Organic Farming Series 1: Some Environmental Problems and their Solutions*. Touhid Publications, Dhaka ISBN 984-32-1154-5 pp 19-50

- M. A. Rahman. 2010. Pollution causing death of city trees. UNB, Dhaka. November 22, 2010.
- M. Domroes (1979). Temporal and spatial variations of rainfall, *J. Nepal Res. Cen.*, 2/3 (1978/79), 49-67.
- M. E. B. Joyner and B. Schaffer. 1989. Flooding tolerance of 'Golden Star' Carambola trees. *Proc. Fla. State Hortic. Soc.* 102:236-239.
- M. Hossain, (1990). Natural Calamities, Instability in Production and Food Policy in Bangladesh. *The Bangladesh Development Studies.* 18(1):33-54
- M. Hossain, (1990). Natural Calamities, Instability in Production and Food Policy in Bangladesh. *The Bangladesh Development Studies.* 18(1):33-54.
- M. Jasimuddin and M. Inoue. 2012. Community Forestry for Sustainable Forest Management: Experiences from Bangladesh and Policy Recommendations. *Formath 11:* 133-166.
- M. K. Hossain, M. K. Alam and M. D. Miah. 2008. Forest Restoration and Rehabilitation in Bangladesh. In: Don Koo Lee (ed.) *Keep Asia Green*, Vol. III, 'South Asia', AKECOP, Yuhan-Kimberly & IUFRO, Vienna, Austria. pp 21-66.
- M. Khalequzzaman, 1994, Recent floods in Bangladesh: Possible causes and solutions. *Natural Hazards*, v. 9, p. 65-80.
- M. Khalequzzaman. 1991. Recent Floods in Bangladesh: Possible Causes and Solution1 (In presented at the International Conference on Natural and Man-made Hazards held in Perugia, Italy, August, 1991; also published in *Natural Hazards*, vol. 9, p. 65-80, 1994.
- M. Khalequzzaman. 1991. Recent Floods in Bangladesh: Possible Causes and Solution. Paper presented at the International Conference on Natural and Man-made Hazards held in Perugia, Italy, August, 1991; also published in *Natural Hazards*, vol. 9, p. 65-80, 1994.
- M. Tsubo, S. Fikai, J. Basnayake and M. Ouk, 2009: Frequency of occurrence of various drought types and its impact on performance of photoperiod-sensitive and insensitive rice genotypes in rain-fed lowland conditions in Cambodia. *Field Crops Research*, 113, 287-296.
- M.A. Miyan, Coastal Zone Management of Bangladesh, Fourth Session of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM-4) (2012) Yeosu, Republic of Korea, May 23-29, 2012
- M.A. Miyan, Coastal Zone Management of Bangladesh, Fourth Session of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM-4) (2012) Yeosu, Republic of Korea, May 23-29, 2012
- M.A. Miyan, Monsoon in Bangladesh; Changes and Adaptation: Asian Monsoon Years AMY-6 (2009), Kunming China November 30-December 01, 2009
- M.A. Miyan, Monsoon in Bangladesh; Changes and Adaptation: Asian Monsoon Years AMY-6 (2009), Kunming China November 30-December 01, 2009
- M.A. Rahman, (2011) Study on the Changes of Coastal Zone: Chittagong to Cox's Bazar along the Bay of Bengal; Global Summit on Coastal Seas, EMECS 9, August 28-31, 2011, Baltimore, Maryland, USA
- M.A. Rahman, (2011) Study on the Changes of Coastal Zone: Chittagong to Cox's Bazar along the Bay of Bengal; Global Summit on Coastal Seas, EMECS 9, August 28-31, 2011, Baltimore, Maryland, USA
- M.A. Rahman, Case Study: The Brahmanbaria Tornado-2013 RCE Bulletin 23, May 22, (2013), http://www.ias.unu.edu/resource_centre/RCE%20Greater%20Dhaka%20-%20Tornado%20in%20Brahmanbaria.pdf accessed on 16th June 2013
- M.A. Rahman, Case Study: The Brahmanbaria Tornado-2013 RCE Bulletin 23, May 22, (2013), http://www.ias.unu.edu/resource_centre/RCE%20Greater%20Dhaka%20-%20Tornado%20in%20Brahmanbaria.pdf accessed on 16th June 2013
- M.A. Rahman, Coastal Zone Management of Bangladesh Presented in the International Geosphere-Biosphere Programme Synthesis Integration and Exploration: Global Environmental Change and Sustainable Development; Needs of Least Developed Countries (IGBP-LDCs) Synthesis Workshop (2010), Maputo Mozambique September 20-22, 2010
- M.A. Rahman, Coastal Zone Management of Bangladesh Presented in the International Geosphere-Biosphere Programme Synthesis Integration and Exploration: Global Environmental Change and Sustainable Development; Needs of Least Developed Countries (IGBP-LDCs) Synthesis Workshop (2010), Maputo Mozambique September 20-22, 2010

- M.A. Rahman, Grey Water Use can Reduce Huge Water Crisis in Dhaka Megacity (2013a) - <http://feppcar.org/280/grey-water-use-can-reduce-huge-water-crisis-in-dhaka-megacity/#more-280>
- M.A. Rahman, Grey Water Use can Reduce Huge Water Crisis in Dhaka Megacity (2013a) - <http://feppcar.org/280/grey-water-use-can-reduce-huge-water-crisis-in-dhaka-megacity/#more-280>
- M.A. Rahman, Model Rural Homestead Farming - A Real Example of Crop Diversification: In Plantation Crops and Organic Farming: Research Articles Series 1: Some Environment Related Problems and Their Solutions: January (2004). ISBN 984-32-1154-5
- M.A. Rahman, Model Rural Homestead Farming - A Real Example of Crop Diversification: In Plantation Crops and Organic Farming: Research Articles Series 1: Some Environment Related Problems and Their Solutions: January (2004). ISBN 984-32-1154-5
- M.A. Rahman, Study on the Changes of Coastal Zone: Chittagong to Cox's Bazar along the Bay of Bengal; Global Summit on Coastal Seas, EMECS 9 (2011), August 28-31, 2011, Baltimore, Maryland, USA
- M.A. Rahman, Study on the Changes of Coastal Zone: Chittagong to Cox's Bazar along the Bay of Bengal; Global Summit on Coastal Seas, EMECS 9 (2011), August 28-31, 2011, Baltimore, Maryland, USA
- M.A. Rahman, Vulnerability of the Bay of Bengal Enclosed Coastal Sea due to Socio-Economic Conditions of the Megacity of Dhaka; Global Summit on Coastal Seas, EMECS 9, August 28-31, 2011, Baltimore Maryland, USA, Published in Indian Journal of Humanities, Vol. 01, Issue 04, (2011), ISSN: 2248-9541Rarahman M.A., 2011
- M.A. Rahman, Vulnerability of the Bay of Bengal Enclosed Coastal Sea due to Socio-Economic Conditions of the Megacity of Dhaka; Global Summit on Coastal Seas, EMECS 9, August 28-31, 2011, Baltimore Maryland, USA, Published in Indian Journal of Humanities, Vol. 01, Issue 04, (2011), ISSN: 2248-9541Rarahman M.A., 2011
- M.A. Rahman, Workshop on Coastal Zone Management, Patuakhali University, (2012)
- M.A. Rahman, Workshop on Coastal Zone Management, Patuakhali University, (2012)
- M.A. Sattar and D.K. Bhattacharjee, Physical and mechanical properties of Sundri (*Heritiera fomes*) and Baen (*Avicennia alba*). Bull. 10. (1987), Chittagong, Bangladesh: Government of the People's Republic of Bangladesh, Forest Research Institute, Timber Physics Series.
- M.A. Sattar and D.K. Bhattacharjee, Physical and mechanical properties of Sundri (*Heritiera fomes*) and Baen (*Avicennia alba*). Bull. 10. (1987), Chittagong, Bangladesh: Government of the People's Republic of Bangladesh, Forest Research Institute, Timber Physics Series.
- M.Ghatak, A. Kamal, O.P. Mishra, (2012) Background Paper Flood Risk Management in South Asia: SAARC Workshop on Flood Risk Management in South Asia, 2012.
- M.H. Rahman, (1995). Responding to Drought in Bangladesh. The Daily Star, May 15:8.
- M.K. Hossain and F.U. Ahmed, Nursery Manual of Endangered Tree Species; Arannyak Foundation, Banani, Dhaka 1213, (2008) ISBN 984-300-001966-0
- M.K. Hossain and F.U. Ahmed, Nursery Manual of Endangered Tree Species; Arannyak Foundation, Banani, Dhaka 1213, (2008) ISBN 984-300-001966-0
- M.S.Combalicer; D.K.Lee; S.Y.Woo; J.O.Hyun; Y.D.Park; Y.K.Lee; A. Edwin; E.A. Combalicer; and Jr. E.L. Tolentino, Physiological Characteristics of *Acacia auriculiformis* A. Cunn. ex Benth., *Acacia mangium* Willd. and *Pterocarpus indicus* Willd. in the La Mesa Watershed and Mt. Makiling, Philippines: Journal of Environmental Science and Management 14-28 (Special Issue 1- (2012) ISSN 0119-1144
- M.S.Combalicer; D.K.Lee; S.Y.Woo; J.O.Hyun; Y.D.Park; Y.K.Lee; A. Edwin; E.A. Combalicer; and Jr. E.L. Tolentino, Physiological Characteristics of *Acacia auriculiformis* A. Cunn. ex Benth., *Acacia mangium* Willd. and *Pterocarpus indicus* Willd. in the La Mesa Watershed and Mt. Makiling, Philippines: Journal of Environmental Science and Management 14-28 (Special Issue 1- (2012) ISSN 0119-1144
- M.Z. Haq; M. Robbani; M. Ali; M.M. Hasan; M.J. Uddin; M. Begum; da Silva, X.Y. Pan, and JAT Karim, Damage and management of cyclone Sidr –affected homestead tree plantations: a case study from Patuakhali, Bangladesh; Received: 3 November 2011/Accepted: 11 July 2012; Springer Science+Business Media B.V. (2012)
- M.Z. Haq; M. Robbani; M. Ali; M.M. Hasan; M.J. Uddin; M. Begum; da Silva, X.Y. Pan, and JAT Karim, Damage and management of cyclone Sidr –affected homestead tree plantations: a case study from Patuakhali, Bangladesh; Received: 3 November 2011/Accepted: 11 July 2012; Springer Science+Business Media B.V. (2012)

- Mahmood, N., Ahmed, S.U. and Loesch, H. 1985: Study on the distribution of finfish larvae in the vicinity of brackishwater aquaculture ponds of Satkhira. Proceedings, Second Intl. Warmwater Aquaculture Conf, Brigham Young University, Hawaii Campus, Honolulu, pp. 109-130.
- Marie Sanderson and Rafique Ahmed (1979) Pre-monsoon rainfall and its variability in Bangladesh: a trend surface analysis Hydrological Sciences-Bulktin-des Sciences Hydrologiques, 24,3, 9/79
- MERIP 2013. Water Conflict and Cooperation in Yemen <http://www.merip.org/mer/mer254/water-conflict-cooperation-yemen>
- Miah, M.S., Haldar, G.C., Rahman, M.A., 1997. Estimation of growth and mortality parameters of Hilsa (*Tenulosa ilisha*, Ham) population in the Meghna river of Bangladesh. Indian J. Fish 44 (2), 133–139.
- Miah, M.S., Rahman, M.A., Haldar, G.C., 1999. Analytical approach to the spawning grounds of Hilsa, *Tenulosa ilisha* (Ham.) in Bangladesh. Indian J. Anim. Sci. 6a, 2.
- Miah, M.S., Rahman, M.A., Haldar, G.C., Mazid, M.A., 1998. Estimation of maximum sustainable yield (MSY) of hilsa (*Tenulosa ilisha* Ham) in the Meghna river of Bangladesh. Bangladesh J. Fish. Res. 2 (2), 177–182
- Michael Woods and Mary B. Woods, In Droughts, Learner Publications Minneapolis MN 55 401 USA ISBN 0-8225-6576-5 (2007) 23-34
- Mimura, N., et al., 2007. Small Islands, impacts, adaptation and vulnerability. In: Parry, M., Palutikof, J., Canziani, O. (Eds.), Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp. 687 – 716.
- Ministry of Environment, Cambodia (2002), Cambodia's Initial National Communication under the United Nations Framework Convention on Climate Change
- Ministry of Environment, Cambodia (2006)
- Miyan, M.A, Coastal Zone Management of Bangladesh, Fourth Session of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM-4) Yeosu, Republic of Korea, May 23-29, (2012)
- Miyan, M.A, Coastal Zone Management of Bangladesh, Fourth Session of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM-4) Yeosu, Republic of Korea, May 23-29, (2012)
- Mohammed, N.; Koike, M., Sajjaduzzaman, M. and Sophanarith. K. 2005. Reckoning social forestry in Bangladesh: Policy and plan versus implementation, Forestry 78: 373–383.
- MoWR (1993) Report on Floods in Bagmati River Basin July 19–21, 1993, Ministry of Water Resources, Government of Nepal, Kathmandu.
- Muluk, C; Ngadiono, K and Partoatmodjo, S.1979: Model development for integrated utilization of land-water interactive resource systems in the coastal part of the citarum watershed <http://www.unu.edu/unupress/unupbooks/80130e/80130E04.htm#>
- N. Islam, 1999, Flood'98 and the future of urban settlements in Bangladesh: Center for Urban Studies, Dhaka, 19 pp.
- N. J. Erickson, Q. K. Ahmad and A. R. Chowdhury, (1993). Socio-economic implications of climate change for Bangladesh. Bangladesh Unnayan Parishad, Dhaka
- N. Karim,: Options for Floods and Drought Preparedness in Bangladesh (2004). [www.grif.umontreal.ca/pages/papers/2004/paper-karim N pdf](http://www.grif.umontreal.ca/pages/papers/2004/paper-karim%20N.pdf), accessed in 11.10.2012
- N. Karim,: Options for Floods and Drought Preparedness in Bangladesh (2004). [www.grif.umontreal.ca/pages/papers/2004/paper-karim N pdf](http://www.grif.umontreal.ca/pages/papers/2004/paper-karim%20N.pdf), accessed in 11.10.2012
- N.Eriyagama,; V. Smakhtin,; N. Gamage, (2009). Mapping drought patterns and impacts: a global perspective. Colombo, Sri Lanka: International Water Management Institute. 31p.
- N.J. Rosenberg ed., (1979), Drought in the Great Plains--Research on impacts and strategies: Proceedings of the Workshop on Research in Great Plains Drought Management Strategies, University of Nebraska, Lincoln, March 26–28: Littleton, Colorado, Water Resources Publications, 225 p. S. Adnan, 1993. Living without Floods: Lessons from the Drought of 1992; Dhaka: Research and Advisory Services.
- NAPA 2005 Ministry of Environment and Forest, Government of the People's Republic of Bangladesh. 2005. National Adaptation Programme of Action. Dhaka, Bangladesh. Ministry of Environment and Forests Government of the People's Republic of Bangladesh.
- NAPA 2005. National Adaptation Programme of Action (NAPA): Ministry of Environment and Forest Government of Peoples republic of Bangladesh.

- NAPA 2006: National Adaptation Programme of Action to Climate Change (Napa)
- NAPA 2012 National Environment Commission Royal Government of Bhutan National Adaptation Programme of Action: Update of Projects and Profiles 2012: National Environment Commission Royal Government of Bhutan <http://www.nec.gov.bt/nec1/wp-content/uploads/2013/04/NAPA.pdf>
- NDMC (2006): National Drought Mitigation Center, 2006. What is drought? Understanding and defining drought.
- NDRMF 2006 National Adaptation Programme of Action: <http://www.nec.gov.bt/nec1/wp-content/uploads/2013/04/NAPA.pdf>
- NOAA, Bay of Bengal large marine ecosystem, (2008) <http://www.eoearth.org/view/article/150447/>
- NOAA, Bay of Bengal large marine ecosystem, (2008) <http://www.eoearth.org/view/article/150447/>
- NPDM-2015, National Plan for Disaster Management 2010-2015 Disaster Management Bureau Disaster Management & Relief Division, Government of the Peoples Republic of Bangladesh; March (2010).
- NPDM-2015, National Plan for Disaster Management 2010-2015 Disaster Management Bureau Disaster Management & Relief Division, Government of the Peoples Republic of Bangladesh; March (2010).
- Nunn, P.,2013. The end of the Pacific? Effects of sea level rise on Pacific Island livelihoods. *Singap. J. Trop. Geogr.* 34 (2),143–171.
- OCHA 2011 Afghanistan: Three million people are affected by drought; <http://www.unocha.org/top-stories/all-stories/afghanistan-three-million-people-are-affected-drought>
- OECD Report 2003 Poverty and Climate Change Reducing the Vulnerability of the Poor through Adaptation <http://www.oecd.org/env/cc/2502872.pdf>
- Orn –uma Polpanich, Drought in Southeast Asia, GEO-DRI Drought Monitoring Workshop, May 10-11, (2010); Winnipeg, Manitoba
- Oxfam 2011, Afghanistan Drought Will Become Disaster Without Aid, Oxfam Says by Jack Phillips for Epoch Times. September 20, 2011, http://en.wikipedia.org/wiki/Drought_in_Afghanistan
- P. Kenyon, (2008) Water, Food Shortages Squeeze Yemen <http://www.npr.org/templates/story/story.php?storyId=90328214> accessed on 14 August 2013
- Palden (2011), “Trashigang: Shortage of Water,” para 11)
- Papricko 2014 <http://gobeshona.net/archives/event/gobeshona-seminar-agrarian-futures-coastal-zone-political-ecology-shrimp-class-climate-change-adaptation-khulna#sthash.ShRtSKpp.dpuf>
- Peter Schwartz and Doug Randall(2003): An Abrupt Climate Change Scenario and Its Implications for United States National Security October 2003
- Peter Schwartz et al (2003) An Abrupt Climate Change Scenario and Its Implications for United States National Security
- R. Ahmed and A. Bernard, (1989). Rice price fluctuation and an approach to price stabilization in Bangladesh. International Food Policy Research Institute, Washington.
- R. Ahmed, and A. Bernard, (1989). Rice Price Fluctuation and an Approach to Price Stabilization in Bangladesh. Washington, D.C.: International Food Policy Research Institute.
- R. Ansari, S. M. Alom and S. S. M. Naqbi. 1999. Response of woody species to salinity. In: Marcal Dekker Inc. (ed.) Nuclear Institute of Agriculture, Sindh, Pakistan. N. E. Marcar, CSIRO, Division of forestry and forest products, Canberra, Australia. S. Ismail, Karachi University, Pakistan. pp 931-946.
- R. Butler 2012: Impact of Deforestation: Local and National Consequences <http://rainforests.mongabay.com/0902.htm>; Laos Mongabay.com
- R. Weir, (2009). Mapping and Analysis of the Resilience of the Food Supply Chain in Scotland. Glengarnock:AEA Technologies for the Scottish Government, 2009.
- R.A. Betts; O. Boucher; M. Collins; P.M. Cox; P.D. Falloon; N. Gedney; D.L. Hemming; C. Huntingford; C.D. Jones; D.M.W. Sexton, and M.J. Web, (2007). Projected increase in continental runoff due to plant responses to increasing CO₂. *Nature*, 448 (7157), pp1037-1041.
- R.A. Warwick, (1975), Drought hazard in the United States: A research assessment: Boulder, Colorado, University of Colorado, Institute of Behavioral Science, Monograph no. NSF/RA/E-75/004, 199 p.)
- R.E. Huschke, (1959), Glossary of meteorology: Boston, American Meteorological Society, pp638
- R.Few, M. Ahern, F. Matthies, S.Kovats (2004). Floods, health and climate change: a strategic review. Tyndall Centre for Climate Change Research. Working Paper 63

- Rafiuddin et.al. (2011) M. Rafiuddin, Badal Kumar Das, Fahiman Khanam, M.N Islan (2011) Diagnosis of Drought in Bangladesh using Standardized Precipitation Index; International Conference on Environment, Science and Engineering, IPCBEE Vol 8, 2011 , pp 184-187, IACSIT Press Singapore
- Rahman et al., (1995). Shrimp culture and environment in Coastal region, working paper, new series no. 8. Bangladesh Institute of Development Studies., Dhaka, Bangladesh.
- Rahman MA, 2011: Vulnerability of the Bay of Bengal Enclosed Coastal Sea due to Socio-Economic Conditions of the Megacity of Dhaka; Global Summit on Coastal Seas, EMECS 9, August 28-31, 2011, Baltimore Maryland, USA, Published in Indian Journal of Humanities, Vol. 01, Issue 04, 2011, ISSN: 2248-9541
- S. Adnan, (1993). Living without Floods: Lessons from the Drought of 1992. Dhaka: Research and Advisory Services.
- S. Agrawala, V. Raksakulthai, M.V. Aalst, P. Larsen, J. Smith, and J. Reynolds., 2003: Development and Climate Change in Nepal: Focus on Water Resources and Hydropower. OECD, pp. 14-28.
- S. Ali, M. D. Subash Chandran and T. V, Ramchandra. 2008. Faunal Assemblages in Myristica Swamps of Central-Western Ghats, Karnataka, India. Centre for Ecological Sciences, Indian Institute of Science.
- S. P. Sah, C. K. Sharma and F. Sehested. 2001. Possible role of the soil in the sissou forest (*Dalbergia sissou* Roxb.) decline in the Nepal terai. In: Horst, W. J., Schenk, M. K., Burkert, A., Claassen, N., Flessa, H., Frommer, W. B., Goldbach, H., Olf, H. W. and Romheld, V. (eds.). International Plant Nutrition, food security and sustainability of agro-ecosystems through basic and applied research, 2001. pp. 930-931.
- S. S. Jallow, Identification of and Response to Drought by Local Communities in Fulladu West District, the Gambia. Singapore Journal of Tropical Geography 16(1) (1995):22-41.
- S. Shahid and H. Behrawan, (2008). Drought risk assessment in the western part of Bangladesh, Natural Hazards, Journal of the International Society for the Prevention and Mitigation of Natural Hazards.
- S.Ferreira, 2011: Nature, Socio-economics and flood-mortality. Proceedings of the 2011 Georgia Water Resources Conference, held April 11-13, at the University of Georgia ,Athens, Georgia, 2011.
- S.K. Baida, R.K. Shrestha, (2007) Climate profile and observed climate change and climate variability in Nepal (final draft). Department of Hydrology and Meteorology Khatmunda, Nepal. 2007
- S.K. Verma, A Textbook of Plant Physiology and Biochemistry; S. Chand & Company Ltd Ramnagar, New Delhi-110 055 Third Edition 1999 ISBN 81-219-0627-X (1999) pp 85-102
- S.K. Verma, A Textbook of Plant Physiology and Biochemistry; S. Chand & Company Ltd Ramnagar, New Delhi-110 055 Third Edition 1999 ISBN 81-219-0627-X (1999) pp 85-102
- S.M. Tareq Integrated Drought Management in South Asia - A Regional Proposal (2012), Global Water Partnership South Asia
- Science Daily (2010): Asia's Most Devastating Droughts Reconstructed
<http://www.sciencedaily.com/releases/2010/04/100422153929.htm>
- A. U. Ahmed, 2004. Adaptation to climate change in Bangladesh: learning by doing. UNFCCC Workshop on Adaptation, Bonn, 18 June 2004.
- Sea-Level Report 2007 http://cc.rsoe.hu/index.php?pageid=events_read&event_id=11 accessed on 18.4.2015
- Sem, G., 2007. Vulnerability and Adaptation to Climate Change in Small Island Developing States: Background Paper for the Expert Meeting on Adaptation for Small Island Developing States. Secretariat of the United Nations Framework
- Shahidullah, M. (1983). Present status of marine fisheries. Country paper, Bangladesh. In: First Meeting of the Technical Liaison Officers, Madras, India, 16–20th August, Bay of Bengal Programme, Marine Fishery Resources Management—RAS/81/051: 16 pp. (Mimeo)
- Singh et.al., In Eucalyptus Enduring Myths, Stunning Realities Abbasi SA, Ramen N and Vinithan S. 2004; Discovery Publishing House 4831/24, Ansari road, New delhi, 110002, India ISBN W8171418929, (1990) pp 26-27
- Singh et.al., In Eucalyptus Enduring Myths, Stunning Realities Abbasi SA, Ramen N and Vinithan S. 2004; Discovery Publishing House 4831/24, Ansari road, New delhi, 110002, India ISBN W8171418929, (1990) pp 26-27
- SMRC Report 26 (2009) Drought Diagnosis and Monitoring over Bangladesh and Nepal; A Collaborative Research Project of SMRC, July 2009 Published by Director, SAARC Meteorological Research Center (SMRC) E-4/C, Agargaon, Dhaka 1207, Bangladesh
https://www.google.com/search?q=Drought+in+Bangladesh+using+spi+by+the+saarc&oq=Drought+&sourceid=chrome&es_sm=122&ie=UTF-8 accessed on 27 April, 2014
- stanin, L.P. and Blagosklonov, K.N. 1983: Conservation of Nature; Progress Publishers, Moscow, 1983
- T. Reardon, P.J. Matlon, and C. Delgado, (1988). Coping with Household-Level Food Insecurity in Drought Affected Areas of Burkina Faso. World Development 16(9):1065-1074.

- T. T. Kozlowski and S.G. Pallardy. 1997b. Growth control in woody plants. Academic Press, San Diego.
- T. T. Kozlowski. 1982. Water supply and tree growth. Part II. Flooding. For. Abstr. 43:145--161.
- T. T. Kozlowski. 1984b. Responses of woody plants to flooding. In: T. T. Kozlowski (ed.) Flooding and Plant Growth. Academic Press, Orlando, FL, pp 129-163.
- T.H. Dewan, M. A. Rahman, S. Miah, Workshop on Environmental Change and Sustainability Development (Report under progress) (2012).
- The Bangkok Post 2010 <http://www.bangkokpost.com/opinion/opinion/33467/china-dams-The-Bhutanese-2012>. Drought in the South screams famine, Met Department data reads otherwise <http://www.thebhutanese.bt/drought-in-the-south-screams-famine-met-department-data-reads-otherwise/> accessed on 14 August 2013
- The Daily Ajker Deshbidesh, October 16, (2008)
- The Daily Ajker Deshbidesh, October 16, (2008)
- The Daily Star, September 16, (2013), Sundarbans Shrinking <http://www.thedailystar.net/beta2/news/sundarbans-shrinking/> accessed on 16th September 2013
- The Daily Star, September 16, (2013), Sundarbans Shrinking <http://www.thedailystar.net/beta2/news/sundarbans-shrinking/> accessed on 16th September 2013
- The daily Star. 2013. A report about the death of many trees along the highway near Brahmanbaria. 21 July, 2013.
- The Yemen Times 2009 Drought and floods in Yemen affect food security <http://reliefweb.int/report/yemen/drought-and-floods-yemen-affect-food-security>
- Ullah, M.H., Mondol, A.I., Uddin M.R. and Ferdous M.A., 2010 Implications of Mangrove Wetland in Socio-environmental Sector: Experiences from Southeast Coast of Chittagong, Bangladesh
- Umme Habiba, Rajib Shaw and Yukiko Takeucki (2011) Socio Economic Impacts of Droughts in Bangladesh In Droughts in Asian Monsoon: Community, Environment and disaster Risk Management Vol 8, 25-28; Emerald Group Publishing Limited.
- UN ISDR (2012) Drought Contingency Plans and Planning in the Greater Horn of Africa, United Nations International Strategy for Disaster Reduction, Regional Office for Africa
- UNCTAD, (2013). The Least Developed Countries report 2013. United Nations Conference on trade and development. Growth with employment for inclusive and sustainable development. Statistical tables On the least developed countries. UNCTAD/LDC/2013.
- UNFCCC, (2008). Physical and socio-economic trends in climate-related risks and extreme
- UN-OHRLS-2009: Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States: The Impact of Climate Change on the Development Prospects of Least Developed Countries and Small island Developing States <http://www.unohrls.org/UserFiles/File/LDC%20Documents/The%20impact%20of%20CC%20on%20LDCs%20and%20SIDS%20for%20web.pdf> accessed on 4th August 5, 2013
- UPI 2011 Severe drought hits Afghanistan http://www.upi.com/Top_News/World-News/2011/10/06/Severe-drought-hits-Afghanistan/UPI-18541317904385/
- Urbano, M., et al., 2010. Climate Change and Children in the Pacific Islands. Nossal Institute for Global Health, University of Melbourne, pp. 1–113.
- V. Krishnamurthy and James L. Kinter III (2002). The Indian Monsoon and its Relation to Global Climate Variability Global Climate; Editor: Xavier Rodo Springer-Verlag <<http://www.bforest.gov.bd>> (Accessed 5 December 2011).
- W. Du, G. Fitzgerald, M. Clark, and X. Hou, (2010) health impact of floods. Prehospital and disaster Medicine 25: 265-72, 2010.
- W. Terink; W.W. Immerzeel, and P. Droogers, (2011), Drought Monitoring and Impact Assessment in the Mekong River Basin; Mekong River Commission Secretariat; Report Future Water: 104; FutureWater, Costerweg 1G, 6702 AA Wageningen, The Netherlands, www.futurewater.nl. http://www.futurewater.nl/wp-content/uploads/2011/11/Mekong_DroughtImpactAssessment_v4_WT.pdf
- WARPO-EGIC, 1996. An atlas of selected maps and spatial data in Bangladesh. Jointly published by Water Resources Planning Organization and Environmental and Geographic Information Center, Dhaka, Bangladesh.
- WeAdapt 2008. <http://weadapt.org/subject/drought>

- WFP 2010: World Food Programme WFP Lao PDR Country Strategy 2011-2015
http://www.wfp.org/sites/default/files/WFP%20Lao%20PDR%20Country%20Strategy_ENG.pdf
- Wickham, F., Kinch, J., Lal, P., 2009. Institutional capacity within Melanesian countries to effectively respond to climate change impacts, with a focus on Vanuatu and the Solomon Islands, Samoa, SPREP, pp. 1–84.
- Wikipedia http://en.wikipedia.org/wiki/Least_developed_country
- Wilhite, D. A. (ed.) (2005). Drought and Water Crises: Science, Technology and management Issues. CRC Press, Taylor and Francis Group. 406 pp.
- World Bank Bangladesh, (2000). Bangladesh agriculture in the 21st century. World Bank Bangladesh Publication, Dhaka, Bangladesh.
- World Bank, 2009. Reducing the Risk of Disasters and Climate Variability in the Pacific Islands: Solomon Islands Country Assessment. World Bank, Washington, pp.1–32.
- World Fish Center, Report, 2008. Towards Sustainable Coastal And Marine Capture Fisheries in Bangladesh: Initiating a Precautionary Approach. 85. The World Fish Center, Bangladesh and South Asia Office, Dhaka.
- [Whttp://wgbis.ces.iisc.ernet.in/biodiversity/sahyadri_enewsletter/issue_23/Article_1/aer4.htm](http://wgbis.ces.iisc.ernet.in/biodiversity/sahyadri_enewsletter/issue_23/Article_1/aer4.htm)
www.irinnews.org
- Y. Yamane, T. Hayashi; A.M. Dewan, and F. Akter: Severe Local convective storms in Bangladesh: Part 1, Climatology, Atmos. Res. 2009 doi.:10. 1016/j.atmosres.(2009).11.004
http://www.iawe.org/WRDRR_Bangladesh/Preprints/S3Hayashi-Yamane.pdf
- Y. Yamane, T. Hayashi; A.M. Dewan, and F. Akter: Severe Local convective storms in Bangladesh: Part 1, Climatology, Atmos. Res. 2009 doi.:10. 1016/j.atmosres.(2009).11.004
http://www.iawe.org/WRDRR_Bangladesh/Preprints/S3Hayashi-Yamane.pdf
- Yevjevich Vujica, W.A. Hall, and J.D Salas, eds., (1977), Drought research needs, in Proceedings of the Conference on Drought Research Needs, December 12-15, 1977: Colorado State University, Fort Collins, Colorado, 276 p.)
- YPSA, Ship breaking in Bangladesh: Environmental Pollution (2010)
<http://www.shipbreakingbd.info/Environment.html>
- YPSA, Ship breaking in Bangladesh: Environmental Pollution (2010)
<http://www.shipbreakingbd.info/Environment.html>
- YPSA, Workers in Ship Breaking Industries: A base line survey of Chittagong, Bangladesh. Young Power in Social Action (YPSA), Chittagong. (2005).pp 79
- YPSA, Workers in Ship Breaking Industries: A base line survey of Chittagong, Bangladesh. Young Power in Social Action (YPSA), Chittagong. (2005).pp 79
- Z. Karim and M.A. Iqbal, (2001): Impact of land degradation in Bangladesh: changing scenario in agricultural land use, Bangladesh Agricultural Research Center (BARC), Dhaka
[Bangladeshhttp://www.researchgate.net/publication/244069875_Drought_Diagnosis_and_Monitoring_o](http://www.researchgate.net/publication/244069875_Drought_Diagnosis_and_Monitoring_over_Bangladesh_and_Nepal)
[ver_Bangladesh_and_Nepal](http://www.researchgate.net/publication/244069875_Drought_Diagnosis_and_Monitoring_over_Bangladesh_and_Nepal)
- Z. Karim, A. Ibrahim, A. Iqbal and M. Ahmed, (1990). Drought in Bangladesh agriculture and irrigation schedule for major crops, Bangladesh Agricultural Research Center (BARC) Publication No. 34, Dhaka, Bangladesh.
- Z. U. Ahmed, Z. N. T. Begum, M. A. Hasan and M. Khandkar. 2008. Encyclopedia of Flora and Fauna of Bangladesh. Vol. 6-12, Asiatic Society of Bangladesh, Dhaka.

Appendices (numerical Appendices attached separately)

Appendix A

Least Developed Countries:

LDCs according to the UNCTAD report on LDCs (UNCTAD, 2008):

- African LDCs (and Haiti): Angola, Benin, Burkina Faso, Burundi, Central African Republic, Chad, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Haiti, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Togo, Uganda, United Republic of Tanzania, Zambia (32).
- Asian LDCs: Afghanistan, Bangladesh, Bhutan, Cambodia, Lao People's Democratic Republic, Myanmar, Nepal, Yemen (8).
- Island LDCs: Cape Verde, Comoros, Kiribati, Sao Tome and Principe, Solomon Islands, Timor-Leste, Tuvalu, Vanuatu (10).
- Some of the island LDCs are geographically in Africa or Asia, but they are grouped together with the Pacific islands due to their structural similarities. Similarly, Haiti and Madagascar are grouped together with African LDCs.

Appendix B: The IGBP/LDCs Synthesis International Steering Committee formed to guide the initially stages of the synthesis

- Opha Pauline Dube - (IGBP, Vice Chair), University of Botswana
- Balgis Elisha – IHDP, African Development Bank and IPCC SREX
- Isabelle Niang - START, 5th IPCC Assessment Coordinating Lead Author
- Rik Leemans – Earth System Science Partnership (ESSP) Chair
- João de Morais - IGBP Deputy Director, Social Sciences
- Mark Stafford Smith – CSIRO and IGBP synthesis Theme Leader: Adaptation
- Carlos Nobre –Brazil IGBP Regional Office
- Rosa Perez - IPCC SREX Lead Author, Ateneo de Manila University Campus
- Alice Newton – IGBP/IHDP core project, LOICZ
- Coleen Vogel – IHDP, University of the Witwatersrand, South Africa

Appendix C:

Table 1. Asia-Pacific Least developed countries (including Oceania SIDS LDCs) as of 2014 (UNCTAD , 2013).

LDC	Land surface area(000sqkm)	Population-2011 (thousands)	Index Income level
Afghanistan	652.2	29105	Low income
Bangladesh	130.2	152862	Low income
Cambodia	176.5	14606	Lower middle income
Bhutan	38.4	729	Low income
Kiribati	0.8	99	Lower middle income
Lao People's Dem. Rep.	230.8	6521	Lower middle income
Myanmar	653.3	52351	Lower middle income
Nepal	143.4	27156	Low income
Timor-Leste	14.9	1176	Lower middle income
Yemen	528	23304	Lower middle income
Samoa	2.8	9908	Lower middle income
Solomon Islands	28	538	Lower middle income
Tuvalu	0 (26 sq km)	10	Upper middle Income
Vanuatu	12.2	242	Lower middle income

I. Conferences/Symposia/Workshops

Seminars and Workshops organized under the Project:

1. Workshop on Disaster Management on October 26, 2012, Department of Disaster Management, Patuakhali University of Science and Technology, Patuakhali, Bangladesh
2. Workshop on Environment Change in 12th November, 2012 : Institute of Forestry and Environmental Science Chittagong University (IFESCU), Chittagong, Bangladesh
3. Write a paper workshop 25-30 August 2013 Windsor Hotel, Bangkok, Thailand
4. Workshop Environment change and disaster management, 8 December, 2014 Bhola, Bangladesh
5. Workshop on Drought Management on 14 October at Rajshahi, Bangladesh

II. **Participation at International Conferences and Scientific Meetings**

- a. Co-Convening an Oral and Poster sessions (Session No.: NH32A and NH33B) on Hydrometeorological and Geophysical Hazards and Disasters in Developing Countries: Risk Perception, Management, and Adaptation. 2015 AGU Fall Meeting, 14-18 December, in San Francisco
- b. Participant: The Gobeshona Conference for Research on Climate Change in Bangladesh 8-11 January 2015, ICCCAD, Independent Univ. Bangladesh, Banani, Dhaka, Bangladesh
- c. Paper Presentation: International Conference on Climate Change in relation to Water and Environment (I3CWE-2015) on 09-11, April, 2015 at Dhaka University of Engineering & Technology, Gazipur, Bangladesh.
- d. Resource Person: 9th Global RCE Conference, Okayama, Japan, November 4-7, 2014.
- e. Participant: UNESCO World Conference on ESD Nagoya, Japan, November 10-12, 2014.
- f. Resource Person, 2nd Regional Consultation Meeting of Experts on “Engaging SAARC for Resilience and Cross Border facilitation for rapid response in disasters”, Kathmandu, Nepal, March 27-28, 2014.
- g. Speaker, Policy Dialogue on Dangerous Demographics on Women, Leadership and the Looming Crisis in Higher Education Colombo, Sri Lanka, March 17-18, 2014.
- h. Resource Person, Conference on Revisiting the MBA in the Asia Pacific Context, Bangalore, India, January 30-31, 2014.
- i. Resource Person, 8th Global RCE Conference, Nairobi, Kenya, November 26-29, 2013.
- j. Team Leader, Write a paper workshop: Global Environmental Change and Sustainable Development in the Asia-Pacific and SIDS Least Developed Countries, Bangkok, Thailand, August 26-30, 2013.
- k. Resource Person, South Asia Regional Consultation on “Climate Change Adaptation – Managing Risk for Resilience (SACCA)”, New Delhi, India, June 24-27, 2013.
- l. Resource Person, Asia Leadership Program on Sustainable Development and Climate Change, New Delhi, India, February 2-17 2013
- m. Resource Person, SAARC Regional Consultation Meeting on “Engaging SAARC for Disaster Resilience”, Islamabad, Pakistan, November 1-2, 2012.
- n. Participant, 7th Global RCE Conference, Tongyeong, the Republic of Korea, September 21-24, 2012.
- o. Resource Person, ADB Leadership Program for Sustainable Development and Climate Change, Manila, Philippines, September 10-14, 2012.
- p. Panelist, 24th AIMS Annual Management Education Convention, Hyderabad, India, August 25-27, 2012.
- q. Attendee Member, 58th Executive Board Meeting of Association of Management Development

- Institutions in South Asia (AMDISA) , Hyderabad, India, August 24, 2012.
- r. Participant, Launching of IPCC's Summary Report on 'Managing the Risks of Climate Extremes and Disasters in Asia - What can we learn from the IPCC Special Report?', Karachi, Pakistan, June 27, 2012.
 - s. Participant, Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM-4), Yeosu, Republic of Korea, May 23-31, 2012.
 - t. Participant, Rotary International 103rd Annual Convention, Bangkok, Thailand, 6-9 May, 2012.
 - u. Participant, Managing the Risks of Climate Extremes and Disasters in Asia - What can we learn from the IPCC Special Report?, New Delhi, India, May 2-3, 2012.
 - v. Convened a session on Global environmental change and sustainable development in least developed countries Impacts of changing planetary pressures: adaptation strategies and disaster risk reduction at the Planet Under Pressure Conference March 26-29 2012, London.
 - w. Attendee Member, 57th Executive Board Meeting of Association of Management Development Institutions in South Asia (AMDISA) , Dhaka, January 23, 2012.
 - x. Participant, Stakeholders Workshop for JCOMM-CHy Coastal Inundation Forecasting Demonstration Project (CIFDP-BSW), Dhaka, Bangladesh, November 28-December 1, 2011.

III. **Funding sources outside the APN**

South Asian Disaster Management Centre (SADMC), IUBAT—International University of Business Agriculture and Technology, Dhaka, Bangladesh has provided material support to the research team from Bangladesh including those who participated from other universities and organizations with working space, work station, internet and telephone support as well as administrative and accounts support to this project. The estimated value of such support could be around US\$20,000.

IV. **List of Young Scientists**

1. Miss Tahmina Akter (BSAg, MSc Ag): Research Assistant, Marine Environment, College of Agricultural Sciences, IUBAT—International University of Business Agriculture and Technology, 4 Embankment Drive Road, Uttara Model Town, Uttara, Dhaka, Cell: 01731648938, E-mail:
2. Mr.Sowmen Rahman (BSC and MSC in Urban Planning): Coastal Zone Management in Bangladesh, Jahangir Nagar University, Savar, Dhaka Cell: 01724178684, E-mail: sowmenurp@gmail.com
3. Mr. Rabiul Islam, Research Assistant (BBA & MBA), IUBAT—International University of Business Agriculture and Technology, 4 Embankment Drive Road, Uttara Model Town, Uttara, Dhaka, Cell: 01731131164, E-mail: rabiul@iubat.edu
4. Md. Majadul Islam (BBA & MBA), Research Assistant, IUBAT—International University of Business Agriculture and Technology, 4 Embankment Drive Road, Uttara Model Town, Uttara, Dhaka

V. **List of Principal Investigators and Co-Investigators**

1. Dr Pauline Dube, University of Botswana, Botswana, dubeop@mopipi.ub.bw
2. Professor M Alimullah Miyan, IUBAT University, Bangladesh; miyan@iubat.edu,
3. Dr Natasha Kuruppu, Institute for Sustainable Futures, University of Technology, Sydney, P.O. Box 123, Sydney, NSW 2007, Australia, Natasha.kuruppu@uts.edu.au
4. Reenate Willie, Kiribati Ministry of Public Works and Utilities, or in Kiribati. PO Box 498, Betio, Tarawa, Kiribati
5. Dr Eberhard Weber, University of South Pacific, Fiji and Solomon Islands., weber_

- e@usp.ac.fj
6. Professor Dev Raj Adhikari, Head, Central Department of Management, Nepal: Nepalese_am@yahoo.com
 7. Dr. M. Shohidullah Miah, IUBAT University: drshohidullah@iubat.edu, www.iubat.edu
 8. Dr Srey Sunleang, Pannasastra University of Cambodia; kampongspeu@puc.edi.kh, kampongspeu@yahoo.com
 9. Mr Tanvir H. DeWan, IUBAT University: thdewan@iubat.edu, www.iubat.edu
 10. Dr. Vo Thanh Son, Centre for Natural Resource and Environmental Studies (CRES)
 11. Dr Mohammed Aatur Rahman, IUBAT University Bangladesh, marahman@iubat.edu
 12. Dr Rehan Dastagir, IUBAT University, Bangladesh: rdastagir@iubat.edu
 13. Mr Sowmen Rahman, Jahangirnagar University, Bangladesh, sowmenurp@gmail.com
 14. Dr Rezaul Karim, IUBAT University, Bangladesh, email: rezaul.karim@iubat.edu
 15. Dr A C Basak, IUBAT University, Bangladesh, email: acbasak@iubat.edu
 16. Shukla Rani Basak, Bangladesh Forest Research Institute, Chittagong, Bangladesh, Email: sr.basak@yahoo.com

VI. Glossary of Terms

APN	Asia Pacific Network
BCCRF	Bangladesh Climate Change Resilience Fund
FAO	Food and Agricultural Organization
GEC	Global-Environmental-Change
GOB	Government of Bangladesh
ICIMOD	International Centre for Integrated Mountain Development
IGBP	International Geosphere Biosphere Program
IPCC	Intergovernmental Panel on Climate Change
IUBAT	International University of Business Agriculture and Technology
IWRM	Integrated Water Resources Management
LDC	Least Developed Countries
MODIS	Moderate Resolution Imaging Spectroradiometer
NAPA	National Action Plan for Adaptation
NCDM	National Committee for Disaster Management
NDMC	National Drought Mitigation Centre
NGO	Non-Government Organizations
NRRC	Nepal Risk Reduction Consortium
NSDRM	National Strategy for Disaster Risk Management
SAARC	South Asian Association for Regional Cooperation
SADMC	South Asian Disaster Management Centre
SIDS	Small Island Developing States
SMRC	SAARC Meteorological Research Centre
SOD	Standing Orders for Disasters
UN	United Nations
UN-ESCWA	UN Economic and Social Commission for Western Asia
WFP	World Food Programme