STATE OF THE ENVIRONMENT

BANGLADESH

2001

DoE

BCAS

SACEP

NORAD

NORWEGIAN AGENCY FOR DEVELOPMENT COOPERATION

UNEP

Bangladesh: State of the Environment 2001

In collaboration with

Published by the United Nations Environment Programme

ISBN: 92-807-2017-1

DISCLAIMER

The contents of this volume do not necessarily reflect the views or policies of UNEP or contributory organizations. The designations employed and the presentations do not imply the expressions of any opinion whatsoever on the part of UNEP or contributory organizations concerning the legal status of any country, territory, city or area or its authority, or concerning the delimitation of its frontiers or boundaries.

The relevant information in this report have been collected from different government and non-government organization, published and unpublished documents and through informal communications. The report uses basic data and information up to 1995 to keep harmony among different environmental issues and concerns due to unavailability of latest data for all sectors.

Cover designed by Purna Chandra Lall Rajbhandari and Ric Dennis A. Canullas
UNEP RRC.AP

Distributed by
United Nations Environment Programme
Regional Resource Centre for Asia and the Pacific
(UNEP RRC.AP)
Outreach Building, Asian Institute of Technology
P.O. Box 4, Klong Luang, Pathumthani 12120
Thailand

Foreword

The Rio Earth Summit in 1992 formulated an action plan, Agenda 21, a multifaceted process to address the full range of development and environmental issues involving participation of governments, international organizations and major groups in the quest for sustainable development.

The publication of the Global Environmental Outlook series, GEO-1, followed by GEO-2000, the Millennium Report on the Environment, involved a participatory assessment process to review the state of the world's environment and to chart a new process for global environmental policy. The diversity and magnitude of environmental problems are outlined, with a call for more complete and precise analyses of the poorly understood linkages between human actions and environmental outcomes. Although the number of policy responses is growing, low priority continues to be afforded to the environment in national and regional planning. GEO-2000 stressed the need for the development of more comprehensive and long-term mechanisms for monitoring and assessing the effects of environmental policies on environmental quality; and for more integrated policy making and action-based programmes to serve the needs of the people.

The United Nations Environment Programme (UNEP) is mandated to produce a Global State of the Environment Report in 2002 (GEO-3) for the 2002 Earth Summit i.e., Rio + 10, and this global assessment will be enriched by producing State of Environment (SoE) reports at the national, subregional and regional levels. In 1998, the UNEP Regional Resource Centre for Asia Pacific (UNEP RRC.AP) collaborated with the Norwegian Agency for Development Cooperation (NORAD) to carry out a process on Strengthening National Capabilities on Environment Assessment and Monitoring towards the Preparation of the Global State of the Environment Report 2002, thus linking national to regional and global initiatives.

This National State of the Environment (SoE) Report of Bangladesh is the one of seven national reports from the above process, focusing on two Asia-Pacific subregions, namely South Asia (Bangladesh, Bhutan, Maldives, Nepal and Sri Lanka) and the Greater Mekong Subregions (Lao PDR and Vietnam). The Department of Environment, Ministry of Environment and Forest (MoEF), the national implementing agency in Bangladesh, has played a very crucial role in carrying out this participatory assessment process in soliciting input from various government sectoral agencies. Around 50 agencies and 110 individuals were involved in the process. With the substantive support from the Bangladesh Center for Advanced Studies (BCAS), the designated national collaborating centre in Dhaka, and regular feedback from the South Asia Cooperative Environment Programme (SACEP), this assessment exercise has been successful and instrumental in providing significant input to the ongoing South Asia SoE Report preparation. It aims at providing guidelines for environmental action planning, policy setting and resource allocation for the coming decades, based on a sound analysis of the state of, and trends in, the nation's environment.

Five priority key issues for the environment of Bangladesh have been identified through a consultative process and analyzed following the "pressure-state-impact- response" (PSIR) analytical framework. The same process has been followed by the other six countries, leading to the identification of their key environmental issues. These can then be addressed subsequently through action-based programmes in the next phase of the planning process.

The five key environmental issues identified for Bangladesh are land degradation, water pollution and scarcity, air pollution, biodiversity, and natural disaster. The rapid population growth and poverty leads to the encroachment of the forest areas for agriculture, and settlements are putting pressure on the existing scarce productive land resources. The improper cultivation, imbalanced use of fertilizer and pesticides, and soil erosion are responsible for the land degradation in the country. The.biodiversity of the country is also threatened by the increasing population pressure and the urban growth which leads to destruction of habitat, over exploitation of flora and fauna, and encroachment of the natural forest. Air qualities, particularly in the cities, are deteriorating due to increase in vehicular traffic and air polluting industries causing adverse health impact to the people residing in these areas. The increasing urbanization and industrialization also resulted to the alarming level of scarcity of water, and pollution on existing water bodies and river system causing long-term effect of water contamination by organic, inorganic, and toxic substances affecting marine aquatic systems. Arsenic contamination of the ground water has emerged as a serious problem

threatening public health. The frequent occurrence of natural disaster like flood, cyclone and storm surge, flash flood, and drought are causing loss of lives and property becomes the major issue for the development planning for the country.

This SoE assessment for Bangladesh provides a sound basis for the development of action plans, the next stage of the planning process, as we enter the new millenium. The report aims to provide concrete guidance for action planning, policy setting and resource allocation for the coming decades to improve the state of the environment of Bangladesh and the welfare of her people.

UNEP will continue to provide leadership in the region for the preparation of environmental assessment reports at national, subregional, and regional level and the capacity building necessary to support these assessment activities.

Klaus Töpfer
Under-Secretary General, United Nations and
Executive Director, United Nations Environment Programme
August 2001

Syeda Sajeda Chowdhury
Minister
Ministry of Environment & Forest

Foreword

Bangladesh is always protective and concerned about the country's environment and its well-being. It takes part in almost all conventions related to sustainable development. As a follow-up to the Inception Meeting for South Asia under SEAMCAP project held in Bangkok during 19-20 April, 1999 a draft National Action Plan was adopted to assist the Ministry of Environment & Forest (MOEF) Govt. of Bangladesh in preparing National State of the Environment (SOE) Report for the period of 1999-2001.

As per National Action Plan, the Department of Environment (DOE) under MOEF has been the designated National SoE Focal Point and the Bangladesh Centre for Advanced Studies (BCAS), the designated Collaborating Centre for preparing Bangladesh State of Environment Report under SEAMCAP.

The project aims at augmenting the capacity of the Government of People's Republic of Bangladesh in making accurate environment assessments, improving the planning processes for sustainable development and establishing a strong information network.

Bangladesh State of the Environment Report 2001 is intended to make the leaders, decision makers and policy-makers of the country aware of the state of environment and to provide early warning of future problems. Compilation of this report had been a challenging task. By successfully publishing this report the Government of Bangladesh has accomplished a goal toward fulfilling national obligation under the Agenda 21. It will also be a contribution of the Government of Bangladesh to the South Asia State of Environment Report and an input to the "2002 Global State of Environment Report" "2002 Earth Summit"

I express my thanks to UNEP/EAP.AP and the Norwegian Agency for Cooperation and Development (NORAD) for their generous financial and technical support towards preparing this report. My special thanks are also due to DoE for acting as the National Focal Point and to BCAS for being the designed Collaborating Centre for carrying out the task successfully.

S. Chowdhury 26-C-2001
Syeda Sajeda Chowdhury
Minister

Acknowledgements

UNEP would like to thank the many individuals and institutions who have contributed to the preparation of *Bangladesh: State of the Environment 200*1. They included individuals from Government Departments, intergovernmental organizations, academic institutions, and voluntary organizations. A full list of contributors, reviewers and participants of the national State of the Environment training and consultation, are included in the Appendix. Special thanks are extended to:

National Implementing Agency
Department of Environment (DoE),
Ministry of Environment and Forest (MoEF),
Government of the People's Republic of Bangladesh

National Collaborating Centre
Bangladesh Centre for Advanced Studies (BCAS), Bangladesh

Funding
The Norwegian Agency for Development Cooperation (NORAD) provided the required financial support needed to the Strengthening Environmental Assessment and Monitoring Capabilities in South Asia and Greater Mekong Subregion (SEAMCAP) Project under which the *Bangladesh: State of the Environment 2001* has been prepared.

SEAMCAP Project Facilitator
Raghunathan Rajamani

Project Management at National Level
Khandaker Rashidul Huq
Quazi Sarwar Imtiaz Hashmi
A. Atiq Rahman
Mozaharul Alam

Editors
A. Atiq Rahman
Saleemul Huq
Amala Reddy
Mozaharul Alam
Sughra Arasta Kabir

SEAMCAP Project Team

UNEP RRC.AP
Surendra Shrestha
Choudhury Rudra Charan Mohanty
May Ann Mamicpic -Bernardo
Mylvakanam Iyngararasan
Purna Chandra Lall Rajbhandari

SACEP
Ananda Raj Joshi
Pradyumna Kumar Kotta

Table of Contents

List of Tables

CHAPTER TWO

CHAPTER THREE

List of Figures

CHAPTER TWO

CHAPTER THREE

1.1 GENERAL BACKGROUND OF THE REPORT

The Bangladesh State of Environment (SoE) Report has been prepared as a response to the recommendations provided in Agenda 21 at the Earth Summit. The objective of the SoE report is to identify the key environmental issues that act as barriers to attain sustainable development, and provide guidelines for environmental planning, policy setting, and provided options that can be undertaken to offset any negative environmental trends. Five environmental issues have been identified on a priority basis as points of national concern. These have been critically evaluated by using the methodology of the Organization for Economic Cooperation and Development (OECD), known as a Pressure-State-Impact-Response (P-S-I-R) framework analysis. The pressures and driving forces responsible for modifying the original state of the resource base and its current status have been critically evaluated. The present conditions of the key issues, along with their subsequent impacts are shown in the report. It also highlights different policies and measures that have been pursued to reduce the pressures on environment, and/or to mitigate the impacts. In order to alleviate further deterioration of present environmental conditions, several appropriate and necessary responses, both in the area of policy and programs, have been proposed. These will enhance and modify environmental conditions in a positive manner, as well as improve the quality of life in Bangladesh.

The United Nations Environment Program (UNEP) initiated the preparation of national and regional SoE reports in May 1999. The present State of Environment Report on Bangladesh has been prepared during the period 1999 to 2001 by the Department of Environment (DoE) under the Ministry of Environment and Forest, Government of Bangladesh, in collaboration with Bangladesh Centre for Advanced Studies (BCAS), a renowned research organization of Bangladesh working in the field of environment and development. The South Asian Cooperative Environment Program (SACEP) and UNEP have provided technical support and reviewed the document, while Norwegian Agency for Development and Cooperation (NORAD) funded for the entire activity. It is also to be noted here that the data and comments regarding the key environmental issues presented in the chapter three of the report have been reviewed by groups of national experts. The findings of the report will be presented at the Earth Summit in 2002.

1.1.1 Methods and Tools

The preparation procedure for the Bangladesh State of Environment Report started in July 1999, through a four-day training workshop that was organized on methods for SoE data collection and reporting. The training was jointly organized by the DoE in association with BCAS, SACEP, and UNEP.

In order to identify key environmental issues two major criteria were kept in mind, which are: (i) severity of the present degradation, and anticipated future trends that have critical implications for attaining sustainable development and quality of life; and (ii) priority, ability and willingness of the country to minimize the degradation processes, and to take protection measures against them. Based on these two criteria five environmental issues have been selected for critical evaluation using the P-S-I-R framework, which cover various important subjects relating to the terrestrial and aquatic environment of Bangladesh, and air quality. The identified key issues are land degradation, water pollution and scarcity, air pollution, biodiversity, and natural disasters.

Potential Key Issue	Impacts
Land degradation	Ecology and quality of life
Water Pollution & Scarcity	Ecology and quality of life
Air pollution	Environment and health
Biodiversity	Ecology, development and quality of life
Natural disaster	Environment, development and quality of life

In the framework, pressures are defined as any fundamental, natural, and manmade forces that influence the state of the environment. State refers to the prevailing conditions of the environment resulting from the pressures, which may lead to various impacts, that can affect human health and well being, as well as socio-economic conditions of the society, and adversely influence the prevailing ecological balance. Responses refer to attempts to mitigate the impacts through the formulation, enactment, and enforcement of necessary laws and regulations by the government, through their relevant agencies. It is to be noted that the evaluation process has also made an attempt to identify gaps, and recommend appropriate options to arrest further deterioration and enhance environmental quality.

The relevant data and information in this report have been collected from different government and non-

government organizations, published documents such as statistical yearbooks, annual reports, project reports (both published and unpublished) and informal communications. Several meetings were conducted with relevant departments, organizational heads, and relevant personnel for collection these data. The data may vary to some extent due to different sources of information.

1.1.2 Format of the Report

The Bangladesh State of Environment report has been prepared based on the format provided by UNEP, and is composed in four Chapters. Chapter one is an executive summary that depicts the status of the key environmental issues of the country. A national overview is given in Chapter two, which includes the natural and ecological resource base of the country, and major environmental concerns in the development context. Chapter three addresses the five key environmental issues based on Pressure-State-Impact-Response (P-S-I-R) analytical framework. For each issue gaps and future options were identified to attain sustainable development by enhancing the environmental resource base. Chapter four is a conclusion with recommendations for immediate actions in the arenas of policy, research, and action.

1.2 OVERVIEW OF KEY ENVIRONMENTAL ISSUES

A summary of the evaluation of the five key environmental issues is presented below.

1.2.1 Land Degradation

Poverty with rapid population growth, absence of a proper land use policy, and other driving forces compel people in Bangladesh to over-exploit natural resources like land, which forms a major focus for human economic activities. The functional capabilities of the soil have deteriorated due to unbalanced use of agrochemicals, unplanned land use, encroachment on forest areas for agriculture and settlements, ineffective implementation of existing laws and guidelines, and improper disposal of hazardous industrial effluents. In addition, urban sprawling and infrastructure development have reduced the availability of land. Natural events such as cyclones and floods cause land loss, and also decrease the functional capabilities of soil. Soil degradation in the coastal area results from unplanned land use, and due to intrusion of saline water. The extent of land degradation varies according to region, season, and year due to the diverse nature of the driving forces and causes.

Land degradation in the Chittagong Hill Tracts (CHT) is occurring mainly due to rapid changes in demography, traditional shifting cultivation practices *(Jhum)*, development of roadways and other physical infrastructure. The Madhupur forest area has been denuded due to deforestation, which has been accelerated by many other factors such as its closeness to the capital city and improved road communication leading to displacement of population, urbanization and industrialization in that area. Land degradation in the Barind Tract is caused mainly due to over exploitation of biomass from agricultural lands, and cultivation of HYV rice through groundwater irrigation. The process has been aggravated by irregular rainfall and insignificant water flow of the rivers that normally play a vital role in replenishing soil fertility and recharge groundwater.

Degradation of soil quality in the floodplains is mainly attributed to improper use of fertilizers and pesticides to boost agricultural production. Gradual siltation in the floodplains also contributes towards degradation of land. Dispersed industrial growth, and uncontrolled discharge of untreated effluents in the nearby floodplain deteriorate the quality of land and soil. Land degradation in the coastal areas of Bangladesh is mainly due to cyclones and storm surges inundating the land. Shrimp cultivation occurs round the year in these areas, which is ultimately increasing the salinity and degrading soil as well. Intrusion of saline water in the dry season is attributed to the low flow in the river system.

Erosion of topsoil in the hill districts has increased, and 17 per cent of the soil resources have deteriorated between 1964 and 1985. It was found that in the mixed forest-covered land, the topsoil erosion rate is 2.7 to 7.2 tons per hectare per annum. On the other hand, in the deforested hill slopes erosion goes up to 120 tons per hectare per annum. A study in Khagrachari, Rangamati, and Bandarban areas on topsoil erosion showed that it ranges from 100 to 120 tons per hectare annually.

The concentration of organic materials present indicates the quality of soil and this has deteriorated significantly in the Barind Tract, Madhupur Tract, Himalayan Foothill areas, the floodplains of *Tista*, *Karatoya*, and *Bangali*, and in the hilly Northeast

region. Moderate deterioration of organic materials has been observed in the medium highlands of the rivers *Tista*, the *Jamuna*, and in the *Ganges* floodplain.

The Soil Resources Development Institute (SRDI) has analyzed soil samples, and found that nitrogen deficiency is common all over the country. The Sylhet *Haor* areas, *Surma-Kushiyara* floodplain, Northeast hilly area, and Madhupur Tract have a noticeable and intense deficiency of phosphorus. A deficiency in other chemical substances has also been noticed in other parts of the country.

Bangladesh is experiencing a decline or stagnation in the yield of many crops. At present, there is meager HYV rice cultivation in the coastal areas. The environment is also unsuitable for cultivation of any other grain during dry period, except wheat where the temperature permits, and early sowing is possible. This is because both dry period *Boro* and wheat are cultivated in the winter season when salinity also reaches to its maximum, and renders most of the coastal land unsuitable for their production.

Real and effective ways to minimize land degradation problems should be based on multi-sectored, multi-layered, yet integrated approaches. The most important policy measure required for addressing land degradation is an integrated land use policy with respect to agriculture, industry and environment. Noting the importance of such an instrument, the Government of Bangladesh has already made some progress in this direction. A Draft Land Use Policy has been prepared, which is under discussion for government approval. This policy also highlights other uses of land for different social and cultural purposes. Certified land ownership is one of the important aspects of the land use policy aimed at reducing ownership-related problems and crime. In order to implement the land use policy successfully, it emphasizes mass awareness programs for the general population and government administration.

Very recently the government has approved the Agricultural Policy of 1999. It also started Integrated Pest Management (IPM) from 1981, which have already been through several phases of research and extension. IPM has an immense contribution to reduce the use of pesticides for crop production. Results show that it has the potential to increase crop production directly, and yet contaminate soil very little. Considering these benefits, the Government initiated the National Integrated Pest Management Policy in 2000. Another concept that is emerging to combat land degradation is called Integrated Plant Nutrient System (IPNS), which involves application of external nutrients based on the soil supplying capacity and the crop need.

1.2.2 Water Pollution and Scarcity

The environment, economic growth and development of Bangladesh are all highly influenced by water - its regional and seasonal availability, and the quality of surface and groundwater. Spatial and seasonal availability of surface and groundwater is highly responsive to the monsoon climate and physiography of the country. Availability also depends on upstream withdrawal for consumptive and non-consumptive uses. In terms of quality, the surface water of the country is unprotected from untreated industrial effluents and municipal wastewater, runoff pollution from chemical fertilizers and pesticides and oil, and lube spillage in the coastal area from the operation of sea and river ports and ship breakage. Water quality also depends on effluent types and discharge quantity from different type of industries, the type of agrochemicals used in agriculture and seasonal water flow, and dilution by the river system.

The concerns over water quality relate not just to the water itself, but also to the danger of diffusion of toxic substances into other ecosystems. The aquatic environment for living organisms can be affected and bioaccumulation of harmful substances in the water-dependent food chain can occur. A variation of inland surface water quality is noticed due to seasonal variation of river flow, operation of industrial units, and use of agrochemicals. Overall, inland surface water quality in the monsoon season is within tolerable limit with respect to the standard set by the Department of Environment. However, quality degrades in the dry season. The salinity intrusion in the Southern region and pollution problems in industrial areas are significant. In particular, water quality around Dhaka is so poor that water from the surrounding rivers can no longer be considered as a supply source for human consumption.

Among the polluted areas, the worst problems are in the River *Buriganga*, where the most significant source of pollution appears to be from tanneries in the Hazaribagh area. In the dry season the Dissolved Oxygen (DO) level in the river becomes very low or zero, so it becomes toxic. The seasonal variation of water quality in the

Buriganga is linked with seasonal variation of water flow and the operation of tanneries. The second most polluted river is the *Sitalakhya*, flowing on the east of Dhaka. The major polluters of this river are Ghorashal Urea Fertilizer Factory, and an oil terminal situated on the bank of the river. Industrial units at Narayanganj and Demra are also the sources of pollution. Monitoring data of DoE demonstrated that the concentration of DO in the river *Sitalakhya* beside the fertilizer factory varies between 2.1 to 2.9 mg/l during low tide. Water of the river *Balu* is badly contaminated by urban and industrial wastes from Tongi and the effluent flowing out through the *Begurbari Khal*, most of which emanates from the Tejgaon industrial area in Dhaka. In the rivers *Balu* and *Turag*, water quality in the dry season becomes worse, with DO concentrations becoming almost zero.

The arsenic concentration in the groundwater is a major problem in Bangladesh now. High levels of arsenic cause serious human health problems if imbibed for a long time (from 5 to 15 years); including skin ailments, damage to internal organs, skin and lung cancers, and eventual death. The recent major studies carried out on arsenic reveal that among 30,000 tubewells studied, 2,000 of them exceeded the national standard of 0.05 mg/l for drinking purposes (the WHO guideline is 0.01 mg/l). The problem is acute in tubewells abstracting groundwater from 10 m to 100 m depths in the Southeast, South Central (the northern part only), and Southwest regions, and occurs to a lesser extent in the eastern part of the Northeast region, and the very southern fringe of the North Central and Northwest (along the river *Ganges*). The most seriously affected districts are in and around Chandpur. It has been estimated that more than 20 million people drink water exceeding the national standard for arsenic levels.

There is a seasonally moveable salinity interface in the coastal area and estuaries, with the threshold limit for agriculture (2dS/m) moving inland in May in the southern part of Bhola and other southern islands. There are also salinity issues in the Southwest region, attributed to reduced dry season flows into the area from the *Ganges* system. During the 1990s dry season, salinity levels in the Khulna area rose, for which one of the likely causes was also postulated to be the decrease in dry season surface flow from the *Ganges.* Surface water scarcity is observed in the Sundarbans, Chittagong, Noakhali, and Dhaka regions, where the ecological and environmental demands for surface water are higher than the supply.

Notwithstanding the large number of rules and regulations to protect water from industrial effluents and other pollution, and the policies for enabling the environment through dry season augmentation of water concerns for the future still prevail. These are regarding proper implementation of national policies, due to the lack of institutional capability and awareness to properly address the policy objectives and goals. The emerging issue of climate change and its adverse impacts on water resources needs proper consideration for planning. Earlier analysis of climate change scenarios showed that water scarcity in the dry season would be aggravated and low water flow in the river system would allow saline water intrusion to progress further inland. Climate change induced adverse impacts on agriculture will put further stress on the country in attaining food sufficiency in the future.

1.2.3 Air Pollution

Air pollution is one of a variety of manmade environmental disasters that are currently taking place all over the world. In Bangladesh, as in other parts of the world, air pollution has recently been receiving priority among environmental issues. Exposure to air pollution is the main environmental threat to human health in many towns and cities. Particulate pollution on its own, or in combination with sulfur dioxide, leads to an enormous burden of ill health; causing at least 500,000 premature deaths, and 45 million new cases of chronic bronchitis each year. The ambient atmospheric conditions have progressively deteriorated due to the unprecedented growth in numbers of passenger vehicles, two-stroke engine vehicles and continuous industrial and residential development.

The ambient air quality of the country is clean in general. However, in urban areas air quality has deteriorated due to human activities. There are two major sources of air pollution in Bangladesh, vehicular emissions and industrial emissions, which are mainly concentrated in the cities. There are also numerous brick-making kilns working seasonally (in dry season) all over Bangladesh which is the other source of air pollution. Almost all of these kilns use coal and wood as their source of energy, resulting in the emission of oxides of sulfur, and volatile organic compounds. In addition

to these usual sources of fuel, spent or used rubber wheels of vehicles are also burnt. These emit black toxic gases that are hazardous to health. Such practices retard the mechanisms for a natural rate of purification of the atmosphere.

Urban air quality monitoring data revealed that the concentration of suspended particulate matter in Dhaka and Chittagong exceeds the threshold limit set by the Department of Environment. A study on the values for average suspended air particulate mass in rural and urban areas of Bangladesh and average elemental carbon in the fine fraction of airborne particulate matter (APM) in urban areas, showed that the concentration of suspended particles in ambient air is many times higher than normal. It also revealed that the PM 2.5 masses and chemical concentrations are lower in most cases compared to the corresponding PM 2.5- PM 10 values. The ratio of PM 2.5 to PM 10, and the amount of black carbon in the APM are reduced during the high rainfall (HRF) period in both rural and urban sites by about 25 per cent and 20 per cent, respectively. In the urban areas, it was found that concentration of SO_2 also exceed the threshold limit quite often in Dhaka. Air quality in Khulna and Bogra is relatively better.

An emerging issue of great concern in the cities and towns is the high concentration of lead in the air from vehicular exhausts. Different studies have shown that the lead concentration has crossed the tolerable limit for human. A study conducted by the Bangladesh Atomic Energy Commission revealed that about 50 tons of lead is emitted annually (with seasonal variation) and the emission reaches its highest level in the dry season.

The Department of Environment and other concerned agencies and organizations, have identified the two-stroke engines used in auto-rickshaws, tempos, mini trucks, and motorcycles as major polluters. Among the polluting vehicles, the two-stroke auto-rickshaws (also called baby-taxis) have been identified as the worst polluters. As present, there are about 35,000 baby taxies among more than 200,000 motor vehicles that ply in Dhaka city alone. The two-stroke petrol engines are less fuel-efficient and emit about 30-100 times more unburned hydrocarbons and carbon monoxide than four-stroke engines; and diesel engines emit 13 times more smoke than non-diesel four-stroke engines. Until mid 1999 all these vehicles used leaded petrol, which was the main culprit responsible for polluting Dhaka's air.

In 1985-86 the Bangladesh Petroleum Corporation started a project to use Compressed Natural Gas (CNG) in vehicles instead of gasoline. The primary objective of this project was to reduce vehicular emissions, as combustion of CNG produces less pollution than gasoline. In response to public pressure and concern regarding air pollution by lead, in July 1999 the GoB executed the decision to provide only unleaded gasoline in the country. However, measurements on lead levels in ambient air after introduction of unleaded gasoline are still not available.

The country does have a reasonably good number of laws and regulations to address air pollution. But there are several additional measures that could be stringently enforced to reduce emissions from vehicles with two-stroke engines, which are the major polluters. Research has shown that it is possible to do this by about two thirds through the use of low-smoke lubricants, and proper inspection and maintenance. Therefore, facilitating this should be an urgent priority in order to improve the quality of air in urban areas.

1.2.4 Biodiversity

Biological resources and diversity form the basis of both the ecology and economy of Bangladesh. The country's agriculture, fisheries and livestock, along with a number of other sectors are heavily dependent, directly or indirectly on biological resources.

Bangladesh possesses good terrestrial and aquatic environment that provide habitat for a large number of plants and animals. The delta is rich in fish and aquatic resources and other biodiversity. Rivers and other inland water bodies provide habitats for 266 indigenous fish species (belonging to 55 families) and 150 species of birds. The inland water bodies are also the habitat of 56 species of prawns. More than 20 species of freshwater molluscs have been identified.

The marine water bodies are also remarkable in biodiversity, harboring 442 species of fish and at least 36 species of marine shrimps. About 336 species of molluscs, representing 151 genera have been identified from the Bay of Bengal. In addition, several species of crabs and 31 species of turtles and tortoises, of which 24 live in freshwater are found in Bangladesh.

In addition, the IUCN Bangladesh Red Data Book (2000) has described 22 amphibians, 126 reptiles, 628 birds in total (388 resident and 240 migratory) 110 inland mammals, as well as 3 species of marine mammals in Bangladesh. There are numerous invertebrates in the country that are yet to be identified. Bangladesh supports approximately 5000 species of angiosperms, among which 300 species are being cultivated. Currently the list of medicinal plants are being revised by the Bangladesh National Herbarium and the number is expected to exceed 500 species. There are 224 species of timber yielding plants and 130 fiber plants found among the flora of Bangladesh.

The Sundarbans support a very rich and diverse fish fauna of 400 species, over 270 species of birds and over 300 species of plants. It is an important staging and wintering area for migratory shore birds, gulls and terns. The Sundarbans comprise the largest remaining tract of habitat for the rare Royal Bengal Tiger *(Panthera tigris)*. St. Martin's Island is an important nesting area for marine turtles and a wintering area for migratory shore birds.

The depletion of biodiversity is the result of various kinds of human development interventions that impinge on it through destruction and degradation of land, forest and aquatic habitats. These activities are in the sectors of agriculture, forestry, fisheries, urbanization, industry, transport, tourism, energy, chemicals and minerals etc. Deforestation and destruction of natural reserve forests in the CHT has been further intensified by development activities such as dams, highways, road construction and other infrastructure development.

In the fisheries sector, shrimp cultivation has become a major concern from the past decade. It has caused serious environmental damage that has harmed fish and other aquatic biodiversity significantly. The physical loss and modification of aquatic habitats for fish, prawn, turtle and other aquatic organisms are said to be the major factors involved in overall fish varieties depletion. Such shrinkage has been the result of thousands of physical structures and drainage systems that have been constructed in Bangladesh in an effort to control floods, cyclones and other natural calamities. These structures have disrupted the natural flow of waters in closed rivers, diverted rivers and have dried up water bodies.

According to the Red List of IUCN, there are 54 species of inland fishes, 8 amphibians, 58 reptiles, 41 resident birds and 40 mammals, which are threatened throughout the country. Among the marine and migratory species of animals 4 fishes, 5 reptiles, 6 birds and 3 mammals are threatened. The Red Data Book on plants, which is still under preparation at Bangladesh National Herbarium, already lists 96 seed-bearing plant species that are threatened.

Bangladesh signed the Biodiversity Convention at Rio in 1992 and ratified it in 1994. A focus on biodiversity has been emphasized in the Forest and Environment Policy. However, a separate policy on biodiversity is yet to be formulated and until then various departments of the government are responsible for conservation of biodiversity. The Bangladesh National Biodiversity Strategy and Action Plan is under preparation as a part of the World Convention on Biological Diversity.

There is a great potential in Bangladesh for biodiversity based sustainable development. In spite of the threatened wild fauna and flora, there are nearly 10,000 species of plants, animals and microbial organisms - a good percentage of which are found in superabundance. A wise and sustainable yield and harvest methodology, and management plan need to be formulated and applied at the field level. So that these biological resources are not over-exploited, and the economy of the country prospers.

1.2.5 Natural Disasters

Bangladesh is a disaster-prone country, the geographical setting and various other anthropogenic activities make the country vulnerable to natural disasters. Almost every year one or more severe natural disasters upset people's lives in some part of the country. Flood is a recurring phenomenon in the country, which brings untold sufferings to millions of people, and results in human deaths, loss of livestock, spread of diseases and hunger, damaged standing crops, destroyed physical and economic infrastructures, damaged fish and shrimp ponds and hatcheries, etc. Cyclone and storm surges occur frequently and cause significant destruction in the coastal areas of the country. Nor'westers and tornadoes also frequently hit different places of Bangladesh. Tropical cyclones and tornadoes have serious and adverse impacts on the economy, as well as on the whole environment, they uproot trees, telephone,

telegraph and electricity lines, destroy bridges, culverts and houses, kill people and domestic animals. Although this country with a monsoon climate usually has enough rain, but often droughts make a negative impact on the agriculture and economy of Bangladesh. The northwestern part of the country is vulnerable to drought. Disastrous land erosion events mainly take place along the banks of the major river systems of the country, i. e., the *Brahmaputra-Jamuna*, the *Ganges-Padma*, the Lower *Meghna*, and other rivers.

Natural disasters cannot be prevented, but the damage can be mitigated with adequate planning and adaptation. The impacts of these disasters vary with their type and magnitude. They also critically depend on institutional strength and response by the different agencies that usually take measures to mitigate and eventually overcome the losses, such as the government, NGOs and other civil service organizations.

The effects of natural disasters may be in direct loss of life and certainly damage to physical property. Thus, the situation necessitates huge resource requirements for disaster management, including mitigation, recovery and preparedness. Otherwise, the consequences of these natural hazards and the resulting environmental degradation, will continue to pose a serious threat to the economic development of the country. Effective disaster management calls for a reliable and timely disaster warning and dissemination system. A timely and accurate alert system regarding impending disasters will help reduce the loss of life and property.

In modern times a whole cascade of risk minimization activities have been identified to address crucial elements of disaster management, which include its prevention, mitigation, preparedness, response, recovery, and development. In order to design these appropriate institutional and functional arrangements for disaster management, the government of Bangladesh has taken initiatives to frame a disaster management policy. Along with the policy, a well planned, carefully designed and action-oriented detailed plan for disaster management is also in the process of preparation. This is of paramount importance to Bangladesh, both at national and local levels, for a coordinated and effective effort to cope with the disaster situation.

There are various Government and community-based organizations working in the field of disaster management and mitigation. But the mechanisms to promote and maintain institutional networking should be enhanced and funds to sustain such programs need to be ensured. Capacity-building activities of various institutions and agencies for mitigation, preparedness, implementation of relief and rehabilitation programs should be strengthened. The capacity building for grassroots and national level monitoring needs to be enhanced at the same time.

1.3 CONCLUSION

The status of the five key environmental issues, viz., land degradation, water pollution and scarcity, air pollution, biodiversity and natural disasters indicates that the environmental condition of the resource base is deteriorating, despite several policy measures undertaken by the different branches of the Government of Bangladesh. Rapid population growth, improper use of land, poor resource management and uncontrolled discharge of pollutants from industries and vehicles are major causes of degradation. There are many underlying reasons that have been identified, including lack of institutional capabilities, untrained human resources, lack of awareness, low community participation in resource management and a paucity of research for enabling policy makers to take proper environmental decisions. Addressing these deficiencies will enable the country in its progress towards attaining sustainable environment and development.

2.1 COUNTRY PROFILE

Bangladesh is a developing country in South Asia located between 20°34′ to 26°38′ north latitude and 88°01′ to 92°42′ east longitude, with an area of 147,570 sq km. It has a population of about 128 million, with a very low per capita Gross National Product (GNP) of US$ 370 (WB, 2000). It has a border on the west, north, and east with India, on the southeast with Myanmar, and the Bay of Bengal is to the south.

Geologically, Bangladesh is a part of the Bengal Basin, one of the largest geosynclinals in the world. The Basin is bordered on the north by the steep Tertiary Himalayas; on the northeast and east by the late Tertiary Shillong Plateau, the Tripura hills of lesser elevation, and the Naga-Lusai folded belt; and in the west by the moderately high, ancient Chotanagpur plateau. The southern fringe of the basin is not distinct, but geophysical evidence indicates it is open towards the Bay of Bengal for a considerable distance. The formation and growth of the Bengal Basin is directly related to the origin and morphology of the Indo-Gangetic trough, which itself is overlaid and filled by sediments thousands of metres thick (Rahman, 1994).

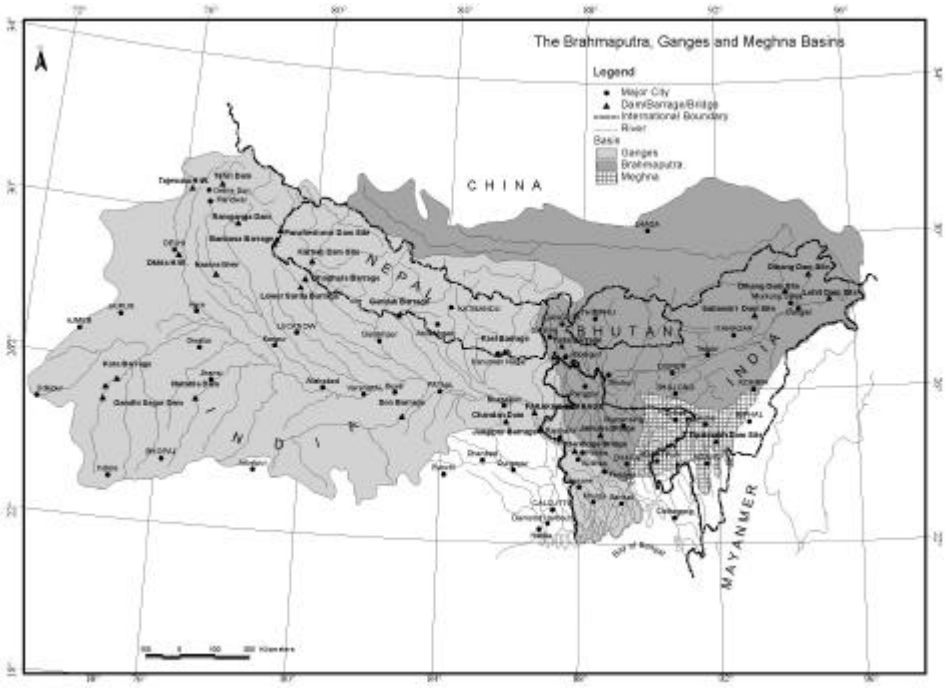
The broad geological features of the Bengal Basin and its prominent tectonic elements are Indian platform, Bengal foredeep, Arakan Yoma folded system, and the Sub-Himalayan Foredeep. Other features are Rangpur Saddle, Dinajpur slope, Bogra slope, Hinge Zone, Barisal High, and Troughs of Sylhet, Faridpur and Hatiya, etc.

The floor of the Bengal Basin consists of quaternary sediments deposited by the *Ganges*, the *Brahmaputra*, and the *Meghna* rivers, known together as the GBM river system, and their numerous tributaries and distributaries. The sediments are washed down from highlands on three sides of the Basin, particularly from the Himalayas, where the slopes are steeper and the rocks less consolidated. Over 92 per cent of the annual runoff generated in the GBM catchment area flows through Bangladesh, although it comprises only about 7 per cent of the total catchment (Coleman, 1969).

The flat topography of the Basin, and the occurrence of recurring floods that cause rivers to change course have complicated the river morphology pattern.

The whole country consists of mainly low and flat land, except for the hilly regions in the northeast and southeast. A network of rivers, with their tributaries and distributaries, crisscross the country.

Figure 2.1.1 Geographical Location of Bangladesh



Source: WARPO Database

Physiographically the country can be divided into hills, uplifted land blocks, and the majority alluvial plains with very low mean elevation above sea level (Rashid 1991). Figure 2.1.1 shows the geographical location of Bangladesh in the context of the GBM river system.

The physical environment of Bangladesh is diverse, and there is a mix of both traditional and modern methods of land use, all very closely adapted to the heterogeneous conditions. This complexity of environment and utilization patterns has important implications for the vulnerability and depletion of the natural resource base. Moreover, neither the physical environment nor technologies remain static. For example, rapid and frequent natural changes are taking place in the river systems, and they are also subject to

the influence of various human interventions. Thus, there are dynamic changes taking place in the hydrological system all the time. These in turn influence land use patterns.

Bangladesh has a comparatively low natural resource base, but a high growth rate of population, with almost half of the population below fifteen years of age. Most of the people are among the poorest in the world, and depend mainly on the natural resource base for their livelihood. But now the resource base is under serious threat, as many natural resources are either being over-exploited or used sub-optimally. Besides the effects of anthropogenic stresses, the low 'land-man' ratio in the country is often further threatened by natural hazards. Thus, for the survival of Bangladesh's dense population, it is essential to have environmental planning and management that conserves and sustains the ecosystems that support their livelihoods.

The high population density, low economic growth, lack of institutional infrastructure, an intensive dependence on agriculture and agricultural products, geographical settings, and various other factors, all contribute to make the country weak in its economic development and quality of life. Table 2.1.1 is a summary of the social, economic, and environmental indicators in Bangladesh from 1981 to 1995.

Table 2.1.1 National Statistics

Indicators	1981	1991	1995
Population (million)	89.9	111.45	119.8
Land Area (square kilometres)	144,000	147,570	147,570
-- Forest (percentage)	15.00	12.80	12.74
-- Agriculture (percentage)	60.52	55.08	52.06
-- Cultivable Wasteland (percentage)	1.62	3.93	4.28
-- Current Fallow Land	3.39	6.49	2.68
GDP in 1989-90 constant price (US$ in million)		26500	32060
GDP in terms of PPP (1990 US$) in billion	NA	NA	125.15
-- Industrial GDP (percentage)		22.14	24.18
-- Services GDP (percentage)		49.45	50.98
-- Agriculture GDP (percentage)		28.13	24.83
GDP per capita (1995 US$)		241	336
PPP per capita of GNP (1995 US	NA	NA	1380
Urban Population as % of Total Population	15.20	17.20	22.00
Population below poverty level	73%	47%	45.8%
Life Expectancy at Birth (years)	55	56	58
Literacy Rate	23.8	32.4	37.2

Source: Population Census 1981, 1991 and Statistical Year Book 1996 of Bangladesh Bureau of Statistics, Draft Fifth Five Year Plan, World Development Report, 1997 of World Bank, Key World Energy Statistics, International Energy Agency, Paris

Figure 2.1.2 Administrative Unit of Bangladesh

Source: WARPO/EGIS National Database

Agriculture, manufacturing industries, and various services such as transport, trade, and housing-related are the major economic sectors of the country. Detailed major sector shares of GDP for the year 1989-90 and 1994-95, at constant (1989-90) prices and current prices, are presented in Table 2.1.2. While there is some debate regarding the direct contribution of agriculture to the national income, two facts remain undisputed. Firstly, there is a decreasing trend in its share. Secondly, despite this, it is still of paramount importance, because of the dependence of most other sectors or activities on it - either for processing its products, or servicing the sector. Therefore, the economy of the country crucially depends upon a high and stable level of agricultural production. Agriculture critically depends upon weather conditions, and is subject to the inherent variability of weather and climate in Bangladesh. Consequently, manufacturing and service sector outputs also become variable. A

Table 2.1.2. Major Sectors Share of GDP

Sector	GDP at current Prices		GDP at constant prices (1989-90)	
	1989-90	1994-95	1989-90	1994-95
Agriculture	25.62	20.32	25.62	21.31
Transport	10.78	12.66	10.78	11.39
Manufacturing	11.44	12.88	11.44	13.62
Trade	16.27	16.80	16.27	17.42
Construction	8.98	8.95	8.98	9.00

Source: BBS, 1997

significant exception to this is the ready-made garments manufacturing industry, which now comprises a significant income sector for Bangladesh.

Economic development of the ever-growing population of Bangladesh is one of the main objectives of planning activities of the Government of Bangladesh (GoB). The GoB has identified poverty alleviation as the principal objective of human resource development, and that it can be achieved through enhanced investment in education to improve human resource potential. However, it is increasingly being recognized in Bangladesh, as in other parts of the world, that for long-term development to be meaningful and sustainable, environmental concerns and planning should be integrated into all development activities. Specific environmental actions are also required for a better future.

Achieving environmentally sound development has emerged as the greatest challenge for the dominant development paradigms all over the world. For a developing country like Bangladesh it has become a formidable task, with its inherent resource constraints, geomorphologic instabilities, political instabilities, weak institutional infrastructure, and paucity of well-established modalities for establishing a framework for sustainable environmental development.

This chapter highlights the present environmental conditions and trends of natural resources and development in Bangladesh, in the context of its physical resources, ecological resources, and quality of life of human resources, i.e., the economic context of the country. It serves as a compilation of relevant background information regarding the key components of the environmental resource base analyzed in the following chapter.

2.2 STATE OF ENVIRONMENTAL RESOURCES

The primary sources of environmental resources in the country can be considered to be the existing natural and human resources. The condition and well being of these two resources are strongly inter-linked. Development primarily depends on the richness and quality of the natural resource base, but in Bangladesh this is very low compared to the density of population, and their demands. In the following section of the report, the environmental resources of the country have been summarized and described under two broad headings, i.e., natural physical, and natural biotic, which reflect the quality of life.

2.2.1 Natural Physical Resources

2.2.1.1 Land and Physiography

Broadly the physiography of Bangladesh can be grouped into three major units: hill soils (12 per cent), old alluvial soils (8 per cent), and recent alluvial soils (80 per cent). The hill soils occupy the Himalayan ranges, Chittagong hills, and the low hills and hillocks of Sylhet, and are derived from tertiary rocks and unconsolidated tertiary and Pleistocene sediments. Old alluvial soils are seen in the tracts of the Madhupur and Barind. The soils of these two tracts have been formed on the old alluvium of the Pleistocene epoch, and are typically reddish to brownish in colour. In addition to these two major Pleistocene terraces, another two minor terraces with old alluvial soil flank the basin, one is east of the Rajmahal Hill system, and the other is to the west of the folded Tripura Hills (Rashid, 1991).

Recent alluvial soils are found in the *Gangetic* alluvium, *Teesta* silt, *Brahmaputra* alluvium, and coastal saline tracts. The deposits of the Ganges and many of its tributaries have formed *Gangetic* alluvium. These soils are rich in calcium, magnesium, potassium, and calcium carbonate. The soils in the *Brahmaputra* alluvium tract include samples of all the fully inundated areas in the region of active rivers. The broad physiographic units of the country are depicted in Figure 2.1.3.

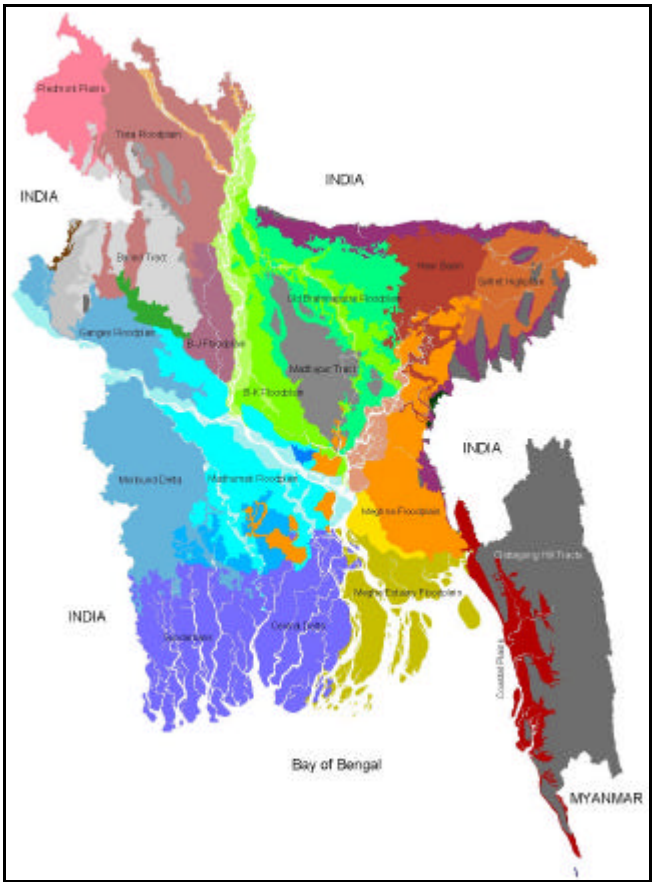
The coastal saline tract is a part of the active flood plain, but is subject to flooding with saline water at

high tides. This tract includes the southern parts of the old districts of Khulna, Barisal, and Patuakhali, and the islands and coastal areas of Noakhali and Chittagong regions. The soils of the coastal districts have some localized variations, both areally and stratigraphically, but consist primarily of fine sands, silts, silty sands, sandy silts, and clayey silts.

A few large depressions, locally known as *beels*, are seen on the delta. The *beels* are usually scars and ox-bow lakes, or back-lands of old riverbeds, but tectonic subsidence is also regarded as one of the causes of the origin of the basins. These major *beels* are mainly found in the *haor* area of Sylhet-Mymensingh. Besides that, there is the Chalan *beel* situated in Rajshahi-Pabna, and Chanda *beel* in the Gopalganj, Faridpur.

The topography of Bangladesh is extremely flat, with local relief ranging between 1 and 2 meters. At least 20 per cent of the area of the country consists of low-lying tidal plains, with elevations of less than 3 meters above sea level. Due to the flat terrain, rivers have extremely low gradients, e.g., 4-5 cm/km for the *Ganges*, 6-10 cm/km for the *Brahmaputra*, and 3 cm/km for the *Meghna* (Rashid and Pramanik 1990).

Figure 2.1.3 Broad Physiography of Bangladesh



Source: WARPO/EGIS Database

As an active delta of three of the world's major rivers, suitable conditions prevail for agricultural activities in Bangladesh. Agriculture is of paramount importance to the country. Most of the land area is occupied by agriculture, forest, and habitat. Less than 1 per cent of the land area is used for industry, and other miscellaneous social needs (Table 2.1.3). Four-fifths of the population depends directly or indirectly upon agriculture. Nearly half of the National Product is from agriculture in Bangladesh.

Table 2.1.3 Bangladesh Land Area Classification, 1990

Landuse Category	Million (ha)	Percent
Agriculture	9.25	64.2
State Forest		
Classified	1.49	10.3
Unclassified	0.73	5.1
Private forest		
Village	0.27	1.9
Tea/Rubber Garden	0.07	0.5
Sub-total (forests)	2.56	17.8
Urban	1.16	8.1
Water	0.94	6.5
Other	0.49	3.4
Sub-total	2.59	18.0
Total	**14.40**	**100.0**

Source: Forestry Master Plan, 1995

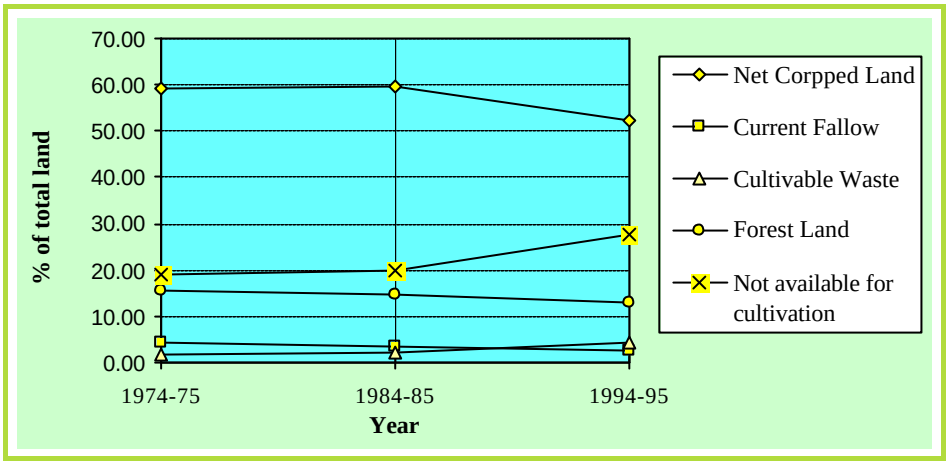
Land use is generally classified into five categories, i.e., cultivated, forest, cultivable waste, current fallow, and not available for cultivation. With the growing population, and their expanding needs in various sectors, land use patterns have changed as shown in Figure 2.1.4, and the "area not available for cultivation" is increasing, which includes land that is mainly urban, rural settlements, and industrial land. On the other hand, the net cropped land, and forestland is shrinking. Almost half of the existing forestland is under different types of non-forest land use now, e.g., shifting agriculture, illegal occupation, unproductive areas, etc.

The major environmental issues relating to land resources span various sectors of the economy, because almost all areas including agriculture, water, forests, habitat, industry, and horticulture, compete for the use of land.

2.2.1.2 Hydrology

Bangladesh is the largest delta in the world formed by the *Ganges*, the *Brahmaputra*, and the *Meghna* river system. This delta is characterized by flat terrain interlaced with the intricate system of rivers and tidal channels, which carry an enormous quantity of sediment-laden water downstream. The three major rivers have a huge catchment area of 1,554,000 sq. km, spreading over five countries, namely, Bhutan, Nepal, China, India, and Bangladesh. There are about 700 rivers, canals, and streams in Bangladesh, with a total length of approximately 22,155 km, which occupies a riverine area of about 9,384 sq. km (BBS 1979, 1998).

Figure 2.1.4 Changes of Land Use from 1975 to 1995



Source: BBS, 1998

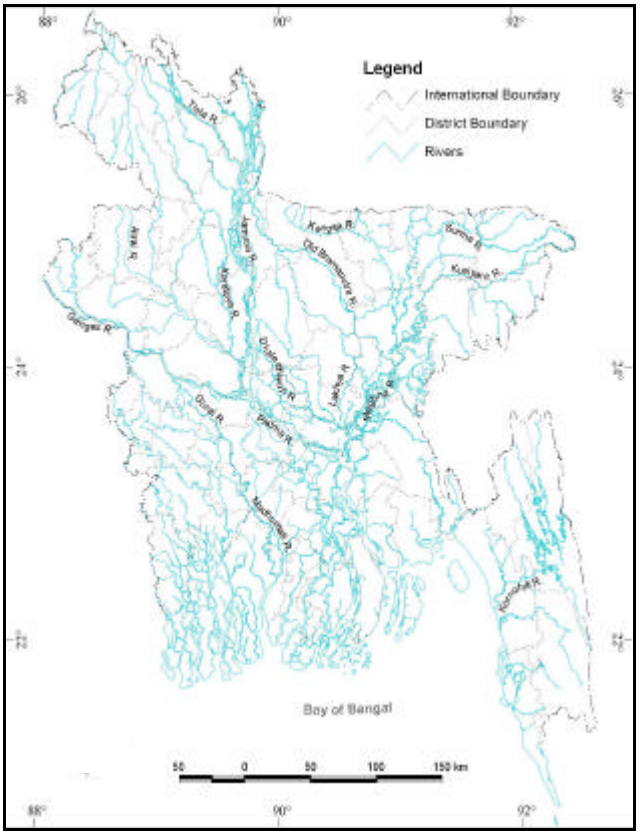
The main river system occupying the delta is formed by the *Ganges* and the *Brahmaputra*, which once they enter Bangladesh are known as the *Padma* and the *Jamuna*, respectively. The *Jamuna* joins the *Padma* near Aricha, and flows up to Chandpur where it joins the *Meghna* and the combined flow is called the *Meghna*. It comprises a large estuary, known as the *Meghna* estuary, at the northeastern apex of the Bay of Bengal.

The *Ganges*, primarily a meandering stream, is about 2,600 km long, and flows parallel to the Himalayan range. It is fed mainly by rivers rising in the southern slopes of the Himalayas and enters Bangladesh at the western extremity of Rajshahi region. The *Brahmaputra* arises in Tibet, and flows in an easterly direction north of the Himalayan range before turning south through the mountains; then it flows west down the Assam valley for a distance of about 700 km, and enters Bangladesh as a wide-braided river, in the region near Majhiali in Rangpur. The meandering *Meghna* river drains the Sylhet Basin and parts of the adjacent Shillong Plateau, and Tripura Hills. The river system of the country is presented in the Figure 2.1.5

The rivers flowing from the hills situated in the southeast of Bangladesh, namely *Feni*, *Karnaphuli*, *Sangu*, *Matamuhuri* and *Knaaf* flow into the Bay of Bengal. The most important river in this region is the *Karnaphuli*, which is also the longest, 274 km.

Thus, a vast amount of water flows through Bangladesh. The rivers of Bangladesh also carry huge amounts of sediment, an estimated 2.4 billion m.tons/year (Milliman and Meade,

Figure 2.1.5 River Systems of Bangladesh



Source: WARPO/EGIS National Database

1983). These sediments are subjected to coastal dynamic processes, generated mainly by river flow, tide, and wind actions. The ultimate result may be additional new land in some places due to accretion, forming islands called *chars*, and loss of land in some other places due to erosion.

Bangladesh is also richly endowed with numerous perennial and seasonal waterbodies known locally as *haors*, *beels*, *baors*, *khals*, *pukurs* and *dighies*. Rivers, canals, *beels*, lakes, and *haors* are open wetlands, while *baors*, *dighis*, ponds, and ditches constitute closed ones. The *haors* are depressions located between two or more rivers, and function as small internal drainage basins. Within the lowest points of the *haor*, there are one or more *beels*, which are lake-like deep depressions retaining water permanently or for a greater part of the year. The *beels* are usually connected to the adjacent rivers by one or more drainage channels, locally termed as *khals*. The *baors* are oxbow lakes from the old meandering bends of rivers that got cut off from the main stream. *Pukurs* and *dighies* refer to ponds of various sizes. To these may be added the vast estuarine systems and mangrove swamps of the south and southeast regions, as well as innumerable man-made water bodies of various sizes.

2.2.1.3 Atmosphere and Climate

The climate of Bangladesh is characterized by high temperatures, excessive humidity, and fairly marked seasonal variations of precipitation. Though more than half the area of Bangladesh is situated north of the Tropics, the effect of the Himalayan mountain chain makes the climate more or less tropical throughout the year. The climate is controlled primarily by summer and winter winds, and partly by pre-monsoon and post-monsoon circulation. The Southwest Monsoon originates over the Indian Ocean, and carries warm, moist, and unstable air. The easterly Trade Winds are also warm, but relatively drier. The Northeast Monsoon comes from the Siberian Desert, retaining most of its pristine cold, and blows over the country, usually in gusts, during dry winter months.

Temperature

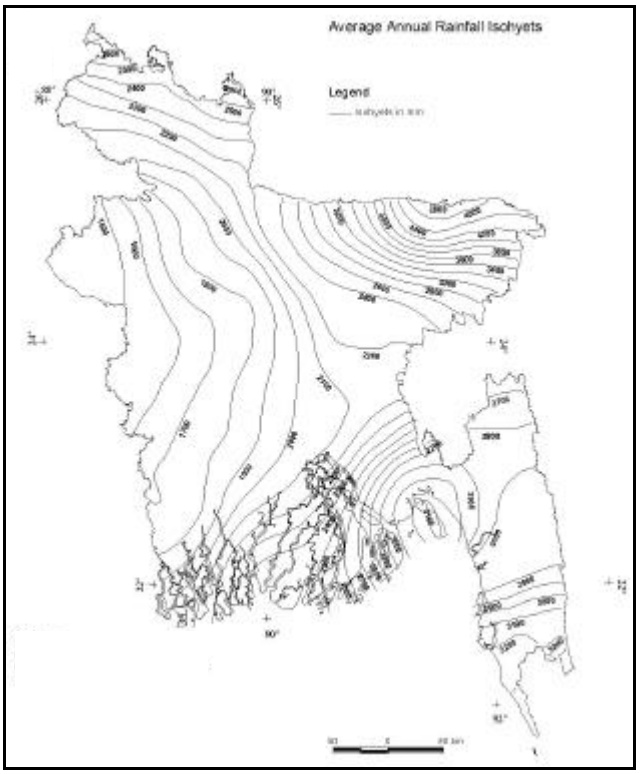
The country has an almost uniformly humid, warm, tropical climate, throughout the country. Traditionally the Bengali year consists of six seasons, namely, Grisho (Summer), Borsha (Rain), Shorot (Autumn), Hemonto (Late Autumn), Sheet (Winter), and Boshonto (Spring). This division based on the harvest cycle is quite reasonable, although there is really no spring or autumn in the sense understood at higher latitudes.

On the basis of temperature (and rainfall), there are three main recognizable seasons as follows:

1) The hot *summer season* from March to June is characterized by high temperatures - 5 to 10 days with more than 40°C maximum in the west, highest rate of evaporation, and erratic but heavy rainfall. The maximum temperatures in the year are reached between the last week of March and the end of April, when average maximum annual temperatures range from 24°C to 34.8°C in different parts of the country. Average minimum annual temperatures range from 11.1°C to 26.4°C.

2) From June to October is the hot and humid *monsoon season* with temperatures ranging from 20°C to 36°C, and heavy rainfall - about two-thirds of the mean annual rainfall. In June there is a marked fall in temperature, because of the monsoon rains. The mean maximum temperature over most of Bangladesh is

Figure 2.1.6 Average Annual Rainfall (Isohyets)



Source: NWRD-Based on daily Rainfall Data from BWDB and BMD for the period from 1966 to 1995

about 31°C, and the mean minimum is 6 degrees less.

3) The relatively cooler and drier *winter* extends from November to March, when temperatures range from 8°C to 15°C, and minimum temperatures can fall below 5°C in the north, though frost is extremely rare. The temperatures fall gradually throughout November and December, and in the last week of December, northern areas of the Northern Region record a maximum of 9°C, and in the Sylhet Hills the mean minimum temperature is 8°C.

In February and March, the temperatures rise again quite sharply. In the west the rise is steep, for example at Rajshahi the temperature goes from 25°C to 32°C. The rise is fastest from the first week of April, when the mean maximum goes up 6°C in Rajshahi, 5°C in Dinajpur, and 4°C in Jessore. In the east, the summers are milder, and the rise in that period is 2°C in Noakhali, 1°C in Chittagong, and very little in Cox's Bazar and Sylhet districts. In Cox's Bazar, the mean maximum rises from 27°C at the end of January to 31°C in the first week of April.

Rainfall

As mentioned briefly above, there are three main periods of rainfall corresponding to the seasons described, each with its distinct source of precipitation. These are:

1) The *pre-monsoon thunderstorms* known as the Nor'westers (North-westerlies) begin about the 10th of March. The Nor'westers arise due to a variety of reasons, the main ones being the steady flow of cool dry air above 1800 meters altitude from the northwest (Anti-Trades), a warm, moist current below 1800 metres from the south, intense evapo-transpiration in the Bengal basin and Assam, and katabatic winds from the surrounding mountains.

2) The heavy *summer rains* known as the Monsoons start from the end of May and continue till mid-October. The main rainy period begins with the coming of the moisture-laden Southwest Trades, popularly known as the Monsoons, which are drawn to the Indian sub-continent by the intense heat, and consequent low pressure over Punjab (in Pakistan and India) and the Upper Ganges Valley. This gives rise to a "tropical cell", with convection currents of massive proportions. These winds blow across the North Indian Ocean, and reach the Malabar Coast of India two weeks before they come up the Bay of Bengal to Bangladesh. One arm of these vast trades moves up the Ganges valley, and brings in rains. It is the orographic rains caused by the striking of this east-flowing air mass against the Arakan Yomas, Meghalaya Plateau, and the Himalayas that forms the major part of the rainfall in Bangladesh.

During the monsoon months the mean cloudiness is from eight to nine-tenths. The total rainfall in these five months varies in different parts of the country. It is 122 cm in the northwestern part at Rajshahi, 149 cm at Narayanganj in the central part, 338 cm in the coastal areas like Cox's Bazar, and over 500 cm in the northeastern part in North Sylhet - across the border from Cherapunji and Mawsyriem, two of the rainiest places in the world (Rashid, 1991).

In most places the maximum rainfall is recorded in June, though July and August record nearly as much. There is a slight difference in rainfall rates in different parts of Bangladesh during the heavy rainfall period. Dinajpur and the northwest of North Bengal, Kushtia, Satkhira, and Noakhali get their maximum rainfall in July. Many places, such as Comillla, Brahmanbaria, Bogra, and Srimangal have a slight tendency to record "double-maxima" in July and in September.

After the 14th October, the monsoon rainfall drops off rapidly. In the western half of the country and in Central Bengal, the rains normally come to an end between the 20th and 25th of October, whereas in the east and southeast, they do not end till about the 10th of November. The rain is very little after this period until the middle of January. At that time, the mean cloudiness is only one to two-tenth.

3) The *western depression of winter rains* occurs mainly from 20th January to 25th February, when it rains from 1 cm to 4 cm.

The mean annual rainfall varies widely within the country according to geographical location, ranging from 1,200 mm in the extreme west to 5,800 mm in the east and northeast. The average annual rainfall is only 273 cm at Chittagong, while Cox's Bazar gets 500 cm or more of rainfall. Nakhyongchhari gets 295 cm annual rain, and to the northeast at Lama

Bazaar it is 300 cm. Further north, Kaptai receives 282 cm, 257 cm at Rangamati, 198 cm at Barkal, and 259 cm at Mainimukh. The rainfall increases northwards, even though the hills are lower, because of the proximity of the Meghalaya Plateau and the Naga Hills. Along the coast the rainfall increases rapidly north of Chittagong, but decreases after the southern-most spurs of the Tippera Hills are passed. In the Surma valley and neighboring hills, the rainfall is very high. In the foothills of South Sylhet, Rashidpur gets 249 cm, Srimangal 253 cm, Patrakhola 216 cm, Kurmah 262 cm, Shamshernagar 269 cm, and near the foot of the abrupt Meghalaya Plateau at Sunamjanj it is 533 cm, and at Lalakhal it is 650 cm - the highest rainfall station in Bangladesh (Rashid, 1991).

In recent years the weather pattern has been erratic, with a reduction of the cool, dry season (Rashid, 1991). This could be a temporary phenomenon, or it may be the beginning of long-term changes due to global warming caused by greenhouse gases. Possible connections with *El Nino* have only now begun to attract attention as a major possible influence on climatic patterns in the Subcontinent.

Fog, Mist, Dew, and Haor-frost

Fog and mist are common features of the weather from November to March. At the beginning and end of this period, mist usually develops at sunset and remains till sunrise, but not fog. In December and January, there is fog on many nights, which may persist even up to noon. Heavy long-lasting fog usually forms in these two months over the *Brahmaputra-Jamuna* River in Sylhet district, and in the Hill Tracts. Dewfall is also very heavy in these two months. Dew possibly accounts for two centimeters or more of precipitation in the wetter areas. Frost may also form in winter on the highest ranges of the Hill Tract districts. Sometimes there are cold air masses from the upper Ganges Valley that lower the night temperatures sufficiently for *haor*-frost to form.

Winds

From November to February, the general directions of the winds are from the northeast in the Northern Region, the northwest over the rest of Western Bangladesh, and from the north in the eastern part. From March to May, the winds are from the west or southwest in the western half, but south-southeast in the eastern half. Occasional Nor'westers change the wind direction of course, and bring relief from the dull heat. From June to September, the winds are not all from the south, much being from the southeast, and even the east. In October the winds are very variable, but there is a definite strengthening of the northern winds, at the expense of those from the southeast. The Inter-Tropical Convergence Zone is in the north of Bangladesh during the four monsoon months, and thus it is a pronounced field of air mass convergence.

2.2.2 Natural Biotic Resources

Terrestrial and aquatic ecological resources play an important role in national development. They serve as rich sources of food and fuel for the population, as well as habitat for the country's biodiversity. Forests provide a wide range of habitat for wildlife, and the wetland ecosystem provides habitat for aquatic species.

2.2.2.1 Terrestrial Ecology

Forests are both environmentally and economically important natural resources in the terrestrial ecosystem. The total land under forest in Bangladesh is about 2.56 million ha, which includes officially classified and unclassified state lands, and forestlands accounted for by village forests and tea or rubber gardens. Although a significant part of the existing forest area is designated as State Forest, most of this land is actually barren of tree vegetation (FMP, 1995). In Bangladesh natural forest areas constitute almost 31 per cent, and forest plantation 13 per cent of forest areas. Only 5 per cent of existing forestlands are designated as protected areas. In terms of per capita forestland, Bangladesh ranks amongst the lowest in the world, with about 0.02 ha per person.

The forests of Bangladesh have been disappearing at an accelerating rate. The good to medium density forest of the Chittagong Forest Division had shrunk from approximately 30,000 ha in 1985 to 20,000 ha in 1992. In Cox's Bazar, natural forest cover dropped from 31,300 ha in 1985, to about 24,300 ha in 1992. In Sylhet only about 6,000 ha, i.e., 15 per cent of the actual forest area had remained in its original state in 1987. In Sundarbans, 78 per cent of the forest had canopy closure of 75 per cent or more in 1961, which was reduced to 65 per cent in 1984. As of 1989 only about 17 per cent of the total legitimate Sal forest area remained across central and northwest Bangladesh (FMP, 1995).

Up to the mid-1980s it was thought that Bangladesh had a deforestation rate of 8,000 ha annually. A recent estimation has shown that there was a loss of 37,600 ha annual forest-cover area over the period 1980-1990, which is a reduction of 3.3 per cent annually. The Forestry Master Plan has mentioned that the status quo scenario will result in the remaining forest largely disappearing over the period of the Plan, except the Sundarbans, which might be spared because of remoteness and poor accessibility.

The major causes of deforestation are industrialization, rapid urbanization, and high population pressure on existing forestland, both for settlement and shifting cultivation. Other causes include encroachment, grazing, fire, uncontrolled and wasteful commercial logging, illegal felling, fuel wood collection, and official transfer of forestland to other sectors, i.e., for settlement, agriculture, and industries. In this way, almost half of the existing forestland is under different types of non-forest use.

In recent years, an estimated number of 109.92 million trees have been planted in the urban areas and as strip plantations along the roads, highways, railways, and embankments. These refer to plantations not classified under GoB-managed (*Khas* land) forest (ALGAS, 1998).

Natural Hill Forests

Hill Forests are the most important major category of woodlands in the country, and comprise more than half the State Forests. They are important from an economic and environmental point of view. The growth rate of Natural Hill Forest is 0.5 to 1.5 m^3/ha/ year. A brief description of the Hill Forests is given below.

Dipterocarp Forests: These forests cover a large part of the wooded area, and consist of mixtures of many tropical evergreen and tropical deciduous trees, occurring in association with bamboo jungles. Though no singletree type is uniformly present or clearly defined over a large tract, in the top storey Garjan (*Dipterocarpus turbinatus*) is the predominant species, and Civit (*Swintonia floribunda*), Narikel (*Sterculia alata*), and Chandal (*Tetrameles nudiflora*) occur in mixture. In the middle storey the important species are Kamdeb (*Anthocephalus chinensis*), Chapalish (*Artocurpus chaplasha*), Nageswar (*Mesna nagesarium*), Pitrajm (*Aphanamixis polystachya*), Jam (*Syzygium sp.*), Bandarhola (*Dhabanga grandifolia*), Champa (*Micheliachampach*) and Toon (*Toona ciliata*). Common tree species in the lower storey are Jam (*Syzygium sp.*), Jarul (*Lagerstromia speciosa*) and Gamar (*Gmelina arboria*). Ecologically this type of forest could be classified into four further sub-sections, i) Tropical Wet Evergreen, ii) Tropical Mixed Evergreen, iii) Tropical Moist Deciduous, and, iv) Tropical Open Deciduous forests.

Savannas: Savannas cover large parts of the Unclassified State Forest of greater Chittagong Hill Tracts, stretching into the Reserve Forests in many places. The vegetation consists of tall grasses (sun grass) with average heights of 1.25 meters, and scattered trees.

Bamboo Forests: Bamboo occurs in abundance, particularly in greater Chittagong Hill Tracts and Sylhet. There are four commercially important bamboo species, namely, Muli (*Melocanna baccifera*), Mitenga (*Bambusa tulda*), Daloo (*Neohouzeana dullon*) and Orah (*Dendrocalamus longispathus*). Muli is the predominant species.

Fresh Water Swamp Forests: These forests occur in low-lying areas of Northern Sylhet. The main species are Hijal (*Barringtonia acutangula*), Jarul (*Lagerstromia speciosa*), and Pitali (*Trewia polycarpa*).

Natural Inland Sal Forest

The Inland Sal Forest is ecologically a Tropical Moist Deciduous Forest in nature. The main species is Sal (*Shorea robusta*), and associated species are Palas (*Butea monosperma*), Haldu (*Adina cordifolia*), Koroi (*Albizia* spp), Bahera (*Terminalia belerica*), Kurchi (*Holarhena antidysentrica*), Haritaki (*Terninalia chebula*), Kusum (*Schleichera oleosa*), Sonalu (*Cassia fistula*), Chaplash (*Artocarpus chaplasha*), and Udal (*Sterculia* sp.). More than 66 per cent of the Sal Forest is denuded or in the possession of encroachers. The growth rate of Sal trees is lower than trees in the Natural Hill Forests.

Littoral Mangrove Forests

The Sundarbans is the major mangrove forest of Bangladesh, lying at the southern extremity of the *Ganges* River Delta, bordering on the Bay of Bengal. The growth rate of this forest is also lower than the natural Hill Forests. Within the mangrove forests there are three distinct belts. *Heritiera fomes*

and *Excoecaria ageallocha* are the dominant species in the slightly saline, and moderately saline zone. In the strongly saline zone, the forest consists mainly of *Excoecaria ageallocha* and *Ceriops decandra* (Goran).

Plantation in Hills

Before 1980, most Hill Forest plantations were Teak and associated species, mainly Jarul and Gamar. Occasionally there were Garjan, Dakijam, and Mahogany. Teak and associated trees are long-rotation crop products for timber. Gamar, Eucalyptus, and Mangium are medium-rotation plantation, for poles, pillar logs, and pulpwood. Short-rotation species are Melucaana, Acacia, and Eucalyptus. The estimated average annual growth is 2.5 and 10 m^3/ha/year for long rotation and short rotation plantations, respectively. For long rotation plantation, the trees are subjected to thinning for years to maintain good timber production.

Inland Sal Plantation

In the early 1950's and 1960's the Bangladesh Forest Department (BFD) raised Sal plantations over large areas. Over the course of the years most of these plantations have disappeared, leaving only a few patches. Later in the 1970's, BFD raised plantations of moderately fast-growing indigenous species on recovered encroached lands. Most of these did not survive either. Then in the 1980's, plantations of eucalyptus and acacia met with the same fate, except some plantations in Rangpur, Dinajpur and Rajshahi division. Under the 'Thana Banayan Plantation Program', enrichment and agro forestry plantation have started again in the Sal forest areas.

Coastal Plantation

In the 1960's Coastal Bangladesh experienced severe cyclone and tidal bores. To protect lives and property from future disasters, the Forest Department started planting trees on the outside of the protective coastal embankments. Now there are about 142,835 ha of coastal plantation.

2.2.2.2 Aquatic Ecology (Freshwater and Coastal Wetland)

For the purpose of the Ramsar Convention as adopted in Ramsar, Iran in 1971, wetlands are defined as areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters. Globally, wetlands are amongst the most fertile and productive ecosystems.

Wetlands are invaluable components of the environment and biodiversity in Bangladesh. Bangladesh possesses enormous wetland areas, among which the principal ones are rivers and streams, freshwater lakes and marshes, including *haors*, *baors*, and *beels*, water storage reservoirs, fish ponds, flooded cultivated fields, and estuarine systems with extensive mangrove swamps. The coastal and inland wetlands encompass the vast floodplains and delta system of the *Ganges*, *Meghna* and *Brahmaputra* rivers. The total area of the wetlands in the country has been variously estimated at seven to eight million hectares, or about 50 per cent of the total land surface.

The biological productivity of these aquatic habitats depends mainly on the activities of plankton, macrophytes, and fauna at the bottom. The chlorophyll-bearing plants are the primary producers initiating the food chain of the aquatic ecosystem. The vegetation thus contributes to the biological cycling and mobilization of chemical elements, which allows the ecosystem to directly support a wealth of fisheries. Aquatic vegetation beds act as spawning grounds and shelter for juveniles of a large variety of fishes and prawns.

The wetlands in Bangladesh are increasingly being recognized as habitat and escape cover for a large variety of wildlife, and a safe nesting site for avifauna. The marsh vegetation associated with wetlands also forms important breeding areas for a wide variety of waterfowl, and roosting places for a large number of resident and migratory birds.

The nutrient products of wetlands in Bangladesh are carried by rivers and floodwater, and benefit the systems downstream. The grazing systems in these regions support cattle that recycle nutrients, enrich soil, and are used as draft animals. The plant diversity provides refuge for predators of pests, e.g., snakes, frogs, and certain fish species, and this helps agriculture in general. Bangladesh does not possess adequate finances and infrastructure for sewage systems on a large scale, but this function is naturally and effectively performed by the wetlands, which serve as a filtering system through recycling of toxic pollutants.

It is the dynamic interaction of terrestrial and aquatic systems in the wetlands with people that makes them so environmentally valuable. They provide a wide range of staple food plants, lush grazing lands, and fuel. Their resources play a significant role in human economic activities like extraction of reeds, and harvesting of food plants and those with medicinal importance. Besides their scenic beauty, which can support the development of tourism, they protect the coastline from erosion, and act as barriers against storm surges.

Disappearing wetlands

The wetlands of Bangladesh are being drastically affected by the impacts of the burgeoning human population. In the *Ganges-Brahmaputra* floodplain alone, approximately 2.1 million ha of wetland have been lost to flood control, drainage and irrigation development. Severe erosion in the catchments areas is causing increased siltation, and having major impacts on the key wetland areas.

Wetlands are being continuously lost or degraded primarily because of various recent developments, such as shrimp culture, which reflect a lack of community awareness of wetland functions and values. Indigenous protective management systems have given way to short-term benefits for a few vested groups. The exploitation of the *haor* wetland ecosystem began due to ever-expanding agrarian settlements, and they are being reclaimed as agricultural land for production of rice. The *beels* are being drained, and embankments built to save crops from flash floods. Apart from these changes in land use patterns, there has also been a decline in fish and migratory birds. Swamp forests that were once extensively distributed, are now on the verge of extermination.

2.2.2.3 Biodiversity

The terrestrial and aquatic areas of the country support a large number of diverse biological populations, both plant and animal. The biodiversity depends on the type and quality of habitat, and level of interference of the human population and development activities. Notwithstanding insufficient baseline information on biological resources, it is believed that development practices have caused a significant depletion of terrestrial and aquatic species diversity. Over-exploitation of some very common species in an unwise manner has led to their being reduced to a vulnerable status; for example, the Freshwater Crocodile is now threatened.

Mangrove forests form a unique environment of floral-faunal assemblages. Leaf litter undergoing decomposition provides particulate and dissolved organic matter to the estuarine ecosystem, and this complex detritus-based food web supports a number of marine and brackish water organisms.

The Sundarbans support a very rich and diverse fish fauna of 400 species, 270 species of birds, and over 300 species of plants. It is an important staging and wintering area for migratory shore birds, gulls, and terns. They comprise the largest remaining tract of habitat for the Royal Bengal Tiger *(Panthera tigris)*. St. Martin's Island is an important nesting area for marine turtles, and a wintering ground for migratory shore birds.

There is an abundance of waterfowl and wetland-dependant birds in the *Haor* Basin. A total of 125 species of waterfowl are known to occur, of which 53 are resident breeding species or breeding summer visitors. During the NERP field program, 284 species of birds were recorded in the Northeast region, of which 89 are true waterfowl. Birds largely or wholly dependent on wetland ecosystems are 30 species, whereas other birds observed in wetlands or adjacent floodplains and dry land are 42 and 123 species, respectively. Despite massive habitat losses, the *Haor* Basin remains an internationally important wintering area for migratory waterfowl, principally ducks and shorebirds. Coastal wetlands support an even larger number of migratory birds, including some highly endangered species.

2.2.2.4 Endangered Species

The adverse effects of recent developments can easily be discerned in the dwindling populations of natural fauna in the wetlands. The Sundarbans now provide the only natural habitat to ensure long time survival in the wild of the world's largest genetically viable population of the Royal Bengal Tiger *(Panthera tigris)*. But the globally endangered Estuarine Crocodile *(Crocodylus porosus)*, which was recorded up to 1950 in Chakaria Sundarbans, has now disappeared from this greatly degenerated and disturbed habitat.

Among the 150 recorded waterfowl in the wetlands of Bangladesh, over 70 are now nearly extinct. The

Grey-leg Goose *(Anser anser)*, Brahminy Duck *(Tadorna ferruginea)*, and Mukra or Comb Duck *(Sarkidiornis melanotos)* have disappeared, while the white winged Wood Duck is almost on the verge of extinction.

The Marsh Crocodile or Mugger *(Crocodylus palustris)* is now represented in Bangladesh by only a few individuals in the large private marsh adjoining a saint's grave at Bagerhat. Another allied species, Gharial *(Gavialis gangeticus)*, is also nearly extinct with an estimated total population of 8-10 individuals. In the wetlands of the *Haor* Basin, seven species of mammals and reptiles are highly endangered. These are the Common Otter *(Lutra lutra)*, Smooth-coated Otter *(Lutra perspicillata)*, Fishing Cat *(Felis viverrina)*, Black Pond Turtle *(Geoclemys hamiltoni)*, Black Monitor Lizard *(Varanus bengalensis)*, Rock Python *(Pytholon molurus)* and Monocellate Cobra *(Naja naja kauthia)*.

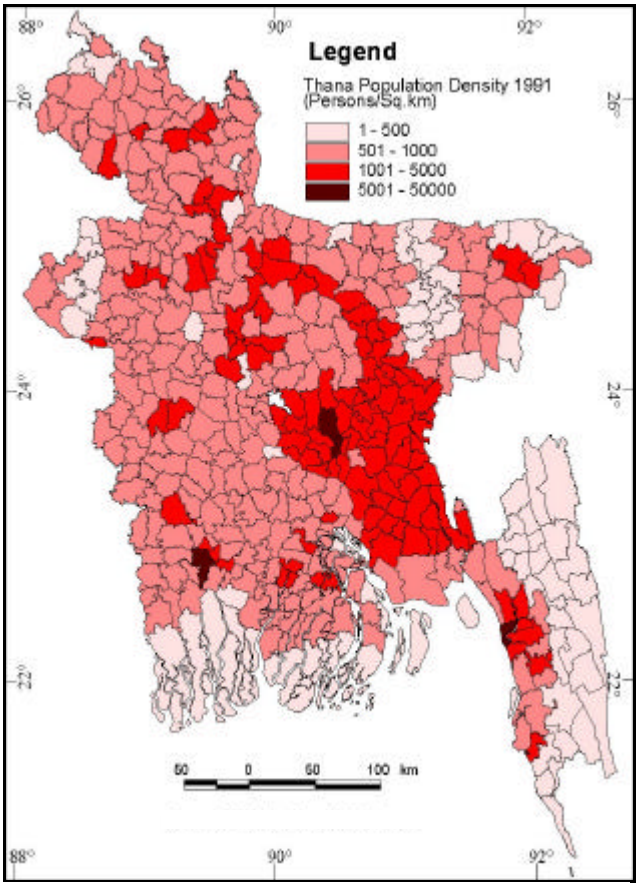
At least four plant species confined to wetland habitats are tentatively listed as threatened. In the *Haor* Basin, Makhna *(Euryale ferox)* is over-exploited for its edible seeds, and the wild rose of Bengal *(Rosa involucrata)* is being depleted at an alarming rate on account of loss of habitat.

2.3 QUALITY OF LIFE

2.3.1 Population Growth

Bangladesh has a population of over 120 million, and with more than 830 persons per sq km is the most densely populated country in the world. Population growth is identified as perhaps the most serious problem inhibiting the sustainable use of resources. Increases in development or productivity are eroded by population growth. At present over 50 per cent of the population in Bangladesh is below 15 years of age. Hence in the next 10 years, there will be a dramatic rise in demand for employment, but opportunities in agriculture appear to be limited, and other sectors are not creating sufficient new jobs. The urban population was 13 million in 1981, and is expected to reach 41 million in 2000. The demand for land is enormous, because of the population density, and a very low land-man ratio intensifies the competition for the very limited land resources for different uses. Conversion of the vast population to a productive human resource remains the greatest development challenge.

Figure 2.1.7 Population Distribution 1991



Source: GIS Division, BCAS

2.3.2 Poverty and Malnutrition

It is estimated that more than 40 per cent of the population regularly consume less than the absolute critical minimum of 1800 kilo calories per day. These 50 million people are amongst the poorest in the world by any standard of development. Furthermore, it has been estimated that the numbers of absolute poor have risen significantly. The poverty of these deprived people is deep rooted, pervasive, and multi-faceted, relating not just to the absence of reliable incomes and productive assets, but also to food, safe water, sanitation, education, shelter, inequities, injustice, and lack of power. These deprived people are also extremely vulnerable to disaster and disease. The challenges posed by this massive poverty are enormous for a country with accelerating environmental degradation of an over-populated land base.

The Human Development Indicators for Bangladesh are also staggeringly low. Bangladesh has an adult literacy rate of 37 per cent, life expectancy of 52.2 years, mortality rate of 109, maternal mortality rate of 650 (in 1986), and a morbidity rate of 18 per cent for

females, and 15 per cent for males. The forecast is that by the year 2001, a quarter of the population will live in urban areas. Urban slum dwellers now account for some 15 per cent of the population, and this is still growing by 6 per cent per annum.

2.4 MAJOR ENVIRONMENTAL CONCERNS

Bangladesh is confronted with a host of environmental issues and problems owing to both natural and human factors. The concerns relate to programs and activities in various sectors, and are of variable nature and intensity. The main environmental issues that are addressed through different policy and planning documents, like the National Environment Management Action Plan (NEMAP), the Fifth Five Year Plan (1997-2002), Environmental Policy, etc., are described briefly below.

2.4.1 Agricultural Resource Base

Over 60 per cent of the total land area in Bangladesh is cultivated. This is one of the highest percentages in Asia. Agriculture represented slightly less than half of the GDP in 1986, and the average annual rate of growth in agricultural production was about 2.7 per cent from 1980-86, which was barely enough to keep pace with population growth. Food consumption affect more than half of the population. In 1992 for the first time the country was self-sufficient in rice, the main staple diet, largely due to a disaster-free year. In the year 2000, the country has produced over 25 million tons of cereals and thus has attained self sufficiently in grain production. Sustainability of this level of production is however a big question. Export volumes are relatively small, and not well diversified.

The vast majority of the population depends on agriculture and natural resources for a large part of their food and income. As a result, agricultural resources in Bangladesh are under severe pressure and environmental strain already. The mechanization of agriculture, and emphasis on high-yielding varieties to grow more food, has resulted in the loss of many traditional varieties of rice and other crops. In addition, the practice of mono cropping has caused serious deterioration of soil characteristics, and a decline in productivity. There are also competing demands on land for non-agricultural uses. Thus, a more dynamic agricultural sector, better use of natural resources, and increased concern for environment are essential. An emphasis on the preservation of biodiversity is necessary to sustain and improve agriculture, forestry, livestock, and fisheries production systems. The indigenous flora, fauna, and ecosystems are important in order to keep future options open, as they form a buffer against harmful environmental changes, and as raw material for scientific and industrial innovations.

2.4.2 Biomass

In Bangladesh biomass plays an important and complex role, especially in the rural areas where about 80 per cent of the people live. At present, there is an acute crisis of biomass fuel, which constitutes 73 per cent of total energy consumption, and the per capita supply is declining. The problem is not merely the supply of wood for fuel or food. There is an increased use of crop residues and dung as fuel, which is depriving the soil of valuable nutrients and organic matter.

2.4.3 Chemical Fertilizers and Pesticides

Modernization of agriculture has led to extensive use of fertilizers and pesticides. Although production of food grain and some other crops has increased significantly, but, as a result of indiscriminate use of these chemicals the quality of the land has suffered. In addition, farmers spraying pesticides because of ignorance often suffer from heart and skin diseases. Cows, goats, and other domestic animals eating pesticide-affected grasses also suffer from the health impacts. Fish populations in the rivers and other water bodies have drastically decreased due to water pollution by chemicals, including fertilizers and pesticides. Application of both fertilizers and pesticides are still very low in Bangladesh, compared to developed countries. Judicious use of these chemicals is essential.

2.4.4 Pollution

The growth of industries in the country has generally been unplanned, without careful consideration of environmental protection issues. There are many industries in residential areas, causing air and water pollution through smoke emission and dumping of untreated effluents. Industrial wastes have polluted the water of the rivers *Buriganga*, *Sitalakhya*, *Karnaphuli*, and others. Effluents from tanneries are extremely

harmful to human beings, since they contain high concentrations of chromium compounds. About 250 tannery units clustered in the Hazaribagh area within Dhaka city are causing serious environmental pollution, and are a health hazard that makes the area unsuitable for human habitation.

2.4.5 Deforestation

Bangladesh has a classified natural forest area of about 10 per cent of the total land area, but only 6-8 per cent of this has good canopy cover, which is far below the desired level. About 50 per cent of the destruction of forests has taken place during the last 20 years, affecting topsoil and causing land erosion. Social forestry and backyard plantations have not yet been able to compensate for such deforestation.

2.4.6 Wetlands and Fisheries

Bangladesh has a high proportion of wetland areas, which of late have been declining. They are significant sources of sweet-water fish, and many other natural resources. The decline in fish production has been attributed to a general deterioration of the wetlands, characterized by silting up of bed levels, water logging, as well as water pollution.

2.4.7 Mangrove Ecosystem

The Sundarbans, located in the southwestern part of Bangladesh, is the largest single expanse of mangrove forest in the world. It is a dynamic, fragile, and complex ecosystem, with a delicate balance of land and water. It is a good habitat for offshore fisheries, offers natural coastal protection, highly valuable forest resources, and tourism and recreational possibilities. But a gradual degradation of environment in the Sundarbans has been taking place due to rapid deforestation, top-drying of trees, saline water intrusion, killing of wildlife, inadequate reforestation, and lack of efficient conservation programs.

2.4.8 Salinity

Diversion of the *Ganges* water upstream through construction of a barrage by India has drastically reduced the downstream flow of its distributaries. Consequently, saline seawater enters the mainland through the rivers. This has adverse effects on agriculture, and sweet-water shrimp cultivation, and also on availability of potable water for domestic and other uses. The situation worsens during the dry season, when salinity penetrates further and deeper into the mainland.

2.4.9 Health and Sanitation

The present sanitation conditions are quite unsatisfactory, particularly in rural areas. Only 36.9 per cent of the population has acceptable sanitary systems for safe disposal of excreta. Raw sewage contamination of water systems in Bangladesh is the major factor in transmission and spread of various communicable waterborne diseases, including diarrhea, cholera, typhoid, etc. Industrial wastes, indiscriminate defecation practices, and unhygienic disposal of human waste often pollute surface water, which is an important source of water for human use, including drinking. The coliform count of most surface water resources is beyond the acceptable standard for any domestic use. The high infant mortality in Bangladesh is attributed to the high prevalence of various waterborne diseases, and unhygienic sanitation practices.

2.4.10 Urbanization

Serious problems of environmental degradation are resulting from unplanned urbanization in Bangladesh. The present pattern of urbanization is leading to various problems like land use alterations; inadequate shelter, water, sanitation, and other facilities in slums and other urban poor areas; degradation of community ambient environment; little control of industrial waste emissions; and environmental pollution due to inadequate management of human and domestic wastes.

The capital city of Dhaka is among the fastest growing cities in the world, with an average population growth of 6 per cent per annum. The environmental problems of Dhaka have become a major concern to all strata of society, including the government, NGOs, and scientists, as well as the country's development partners and aid agencies. The World Bank and the Asian Development Bank have sponsored a number of studies and public consultations on environmental issues in Dhaka city. Apart from air pollution, household solid waste poses a serious threat to the city's environment. According to an estimate, 700-800 tons of household and commercial solid wastes are produced in the dry season, and 900-1100 tons during the monsoon season. The wastes are dumped

untreated in nearby low-lying areas and water bodies, where they pollute surface water and generate a foul odor. The hazardous medical wastes from a large number of clinics and hospital are believed to go through the same type of untreated disposal.

2.4.11 Water Pollution

Although Bangladesh is relatively backward and in an early stage of industrialization, the congested location of industrial units and some commercial activities can be identified as environmental hazards, causing severe local water pollution. The tanneries at Hazaribagh in Dhaka city, the textile and dying units at Narayanganj and Gazipur near Dhaka, and the commercial shrimp culture in the coastal regions of Khulna and Chittagong are some of the environmental "hotspots" that have been identified in the country.

More recently, arsenic contamination of the groundwater has emerged as a serious problem threatening public health. In the past decades, groundwater was considered a source of safe drinking water, and was promoted through the installation of thousands of tube wells in rural areas throughout the country. During this period there was remarkable success in providing pure drinking water, free from pathogenic microorganisms, and a concomitant improvement in public health. Then a few years ago, arsenic contamination of groundwater was detected in 44 of the country's 64 districts. Although the real causes of arsenic contamination are yet to be identified, the government has launched a US $50 million project with assistance from donors, and coordinated by the World Bank, for on-site mitigation of arsenic contamination, and the creation of a National Arsenic Mitigation Information Centre (NAMIC).

2.4.12 Global Warming and Climate Change

There is firm scientific evidence that the concentration of greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, in the earth's atmosphere is increasing, largely due to human activities. The consequences will be progressive global warming and climate change. The outlook for any particular country is still not fully clear, because of large uncertainties regarding the rate and magnitude of warming. However, preliminary studies in the past few years have yielded scenarios of Bangladesh's probable vulnerability to climate change.

It is expected that Bangladesh may get warmer and wetter owing to global warming. Higher precipitation may increase the area and depth of flooding, which will require additional measures for protection and adaptation. Other probable impacts include, disruption of the monsoon rhythm, prolonged drought, and increased frequency of cyclones. The most serious consequence of climate change for Bangladesh will be a rise in sea level along the Bay of Bengal coast, causing submergence of 10 to 20 per cent of the land (including the Sundarbans), as well as saline intrusion in the rivers. Although climate change is a long-term process, the implications for Bangladesh are vital for further policy planning.

Reference

ALGAS (1998) *Asian Greenhouse Gas Abatement Strategy: Bangladesh*, Asian Development Bank, Manila.

BBS (1979) *Statistical Year Book of Bangladesh*, Bangladesh Bureau of Statistic, Ministry of Planning, Dhaka, Bangladesh.

BBS (1997) *National Accounts Statistics of Bangladesh (Revised Estimates, 1989-90 to 1994-95)*, Bangladesh Bureau of Statistic, Ministry of Planning, Dhaka, Bangladesh.

BBS (1998) *Statistical Year Book of Bangladesh*, Bangladesh Bureau of Statistic, Ministry of Planning, Dhaka, Bangladesh.

Coleman, J.M. (1969) *Brahmaputra River: Channel Processes and Sedimentation*. Sedimentary Geology, B129-239.

FMP (1995) Forestry Master Plan, Forest Department, Ministry of Environment and Forest, GoB, Dhaka, Bangladesh.

Milliman, J.D. and Meade, R.H. (1983) World-wide Delivery of River Sediment to the Oceans. *J. of Geol*., 91, pp 1-21.

Rahman, A.A., Saleemul Huq, Raana Haider, Eirik G. Jansen, 1994, Environment and Development in Bangladesh, The University Press Limited, Dhaka, Bangladesh.

Rashid, H., 1991, Geography of Bangladesh, The University Press Limited, Dhaka, Bangladesh.

Rasid, Harun and Pramanik, M.A.H., 1990. *Visual Interpretation of Satellite Imagery for Monitoring Floods in Bangladesh*. Springer-Verlag New York Inc. U.S.A.

WB (2000) *World Development Report 2000/2001*, World Bank, Oxford University Press , Inc., New York.

3.1.1 INTRODUCTION

Land is the basic natural resource that provides habitat and sustenance for living organisms, as well as being a major focus of economic activities. Degradation of land refers to loss of its potential production capability as a result of degradation of soil quality and also its loss for effective use. In Bangladesh, the topsoil degrades due to natural processes and human activities. The functional capabilities of soil deteriorate from activities related to agriculture, forestry, and industry. On the other hand, urban sprawling and infrastructure development cause loss of available land. Natural events such as cyclones and floods cause land loss, and can also deteriorate functional capabilities of soil. Soil degradation in the coastal area results from unplanned land use, as well as intrusion of saline water. Therefore, solving or minimizing land degradation problems should be based on multi-sectored, multi-layered, yet integrated approaches.

The land degradation section of this report deals with causes of land degradation, both in terms of deterioration of soil quality and loss of land. It also highlights state and impacts of degradation, along with policy and program responses.

There are several issues related to land degradation that intersect with other concerns. The most relevant of these have been addressed in other chapters of the report. For example, land related environmental problems, particularly droughts and floods, have been discussed under the Natural Disaster section. The Biodiversity section addresses issues of shrinking wetland in the dry season. The Water Pollution and Scarcity section deals with lean water flow in the river system and fluctuation of groundwater.

3.1.2 PRESSURES

There are many driving forces compelling people in Bangladesh to over-exploit natural resources like land. The main ones are the poverty with rapid population growth, improper land use, absence of a land use policy, and ineffective implementation of existing laws and guidelines. Unplanned agricultural practices, and encroachment on forest areas for agriculture and settlements, also put pressure on scarce land resources. Unplanned or inadequate rural infrastructure development and the growing demands of increasing urbanization are also devouring productive land. The level of land degradation and its extent vary seasonally and yearly, by region, as well as the pressures on land are not always the same either.

Natural processes that lead to land degradation in Bangladesh can be considered part of the ongoing land formation process. The upliftment and deposition processes that led particularly to formation of land in the regions of Sylhet, Chittagong, Barind and Madhupur continued during the period of the Miocene, Pliocene and Pleistocene ages. Throughout the Pleistocene time up to the present, the rivers have been depositing heavy sediments to build up the country's flat alluvial plain, although the processes of erosion and deposition have not been similar all along. There are a few studies on recent sedimentation and erosion that show these processes have been aggravated by human interventions such as encroachment for settlement and improper agricultural practices.

Land degradations caused by nature are often balanced by formations of new land. Deterioration of soil quality and land loss due to human intervention may not always be reversible.

If the pressures on land are considered in a region-wise manner, the following picture emerges:

Land degradation in the Chittagong Hill Tracts (CHT) is occurring mainly due to rapid changes in demographic patterns, development of roadways and other physical infrastructure. *Jhum* cultivation, the traditional community-based agricultural method practiced by the indigenous people of the CHT, is one of the major causes of land degradation. Degradation of land in the hilly area has also occurred due to the mobilization of defense regiment for peace keeping in the CHT, which leads to destruction of forestland and loss of land cover.

The Madhupur forest area has almost been denuded due to deforestation and has further been aggravated by many other factors such as its closeness to the capital city, improvement of road communication leading to displacement of population, urbanization and industrialization. This land, a Pleistocene terrace, is naturally raised and flood-free, therefore, it is attractive for infrastructural development. The land in the area has further been degraded by the development activities related to building of the Jamuna Multipurpose Bridge.

Land degradation in the Barind Tract is caused mainly due to over exploitation of biomass from agricultural

lands and unscientific cultivation of HYV rice through groundwater irrigation. The process has been aggravated by irregular rainfall; and insignificant water flow in the adjacent rivers that normally play a vital role in replenishing soil fertility and recharging groundwater.

Degradation of soil quality in the floodplains is mainly attributed to improper use of chemical fertilizers and pesticides to boost agricultural production. Siltation in the floodplains also contributes towards degradation of land due to flashflood and sediments accumulated from riverbank erosion. Dispersed industrial growth and uncontrolled discharges of their untreated effluent in the nearby rivers deteriorate the quality of land and soil.

Land degradation in the coastal areas of Bangladesh is a result of recurring cyclones and storm surges, which inundate the land. Practice of shrimp cultivation round the year is ultimately increasing the salinity of the degraded soil. Intrusion of saline water in the dry season is attributed to the low flow in the river system.

Human interference and waterborne action are the two most important land degradation processes in Bangladesh. Table 3.1.1 presents driving forces and pressures, state, impacts related to land degradation and responses to address the problems.

3.1.2.1 Human Activities

Improper Cultivation in Hill Slopes, Terrace Land and Piedmont Plains

Shifting cultivation on the hills, locally known as "*Jhum*", is a common practice among the tribal communities in the greater Chittagong Hill Tracts. Traditionally *Jhum* cultivation is a slash-and-burn process where a certain area is cleared and cultivated

Table 3.1.1 Pressures, State, Impacts and Responses of Land Degradation

Driving Forces & Pressures	State	Impacts	Responses
• Population and Poverty	• Increasing population	• Depletion of natural resource base	• Population control and poverty alleviation program. [E]
• Improper agricultural practices	• Unscientific use of agricultural inputs (chemical fertilizer and pesticides)	• Yield reduction due to quality degradation of soil and thus decriseing land productivity	• Integrated Plant Nutrient System (IPNS) • Integrated Pest Management (IPM). [E] • Induction of green manuring crop, biomass recycling. [E]
• Agriculture practices in hill, terrace and piedmont area	• Deforested area	• Loss of topsoil • Gradual siltation in the floodplain and water bodies	• Occasional restriction and ban of *Jhum* cultivation [E] • Massive afforestation [E] • Adoption of SALT (Sloping Agricultural Land Technology)
• Improper irrigation	• Declining soil nutrient	• Yield reduction due to quality degradation of topsoil	• Irrigated Agricultural Development Strategies [E] • Use of surface water for irrigation [E]
• Development of rural road network	• Increased length of road	• Loss of productive agricultural land	• Draft Land Use Policy [P] • Integrated road, embankment and drainage system
• Mining of sand and gravel	• Abandoned area is increasing	• Loss of productive land	• Draft Land Use Policy [P]
• Land ownership and tenure	• Land fragmentation	• Quality degradation	• Draft Land Use Policy [P]
• Riverbank erosion and sedimentation	• Erosion and accretion of land	• Loss of land and quality degradation	• Riverbank protection and embankment [E]
• Salinity	• Salinity intrusion	• Quality degradation	• Augmentation of dry season flow [E/P]
• Industrial pollution	• Open discharge to land	• Quality degradation	• Environment Protection Act and Rules (95/97) [E]
• Rural housing	• Horizontal expansion of	• Seizing of productive land	• Vertical expansion of rural housing [P]
• Urbanization	• Increased unplanned land use	• Loss of land	• Draft Land Use Policy [P]
• Brick making and kiln	• Number of brick kilns are increasing	• Loss of topsoil • Destruction of productive land	• Draft Land Use Policy [P] • Environment Protection Act and Rules (95/97) [E]

Source: SoE Study Team
Note: E stands for Existing and P stands for Proposed

for 1-2 years, and then abandoned for 5-12 years until the natural fertility of the soil is regained to a useful economic level (Rahman, 1991). In the recent years this traditional agricultural practice is considered as the most inefficient way of using the rich forest lands. Due to increase in the number of population in the CHT region there is a demand on agricultural production, which is putting pressure on cultivable land. As a result, the traditional regeneration time is not being allowed, and the soil is loosing its fertility.

A view of hill slope agriculture

Clearing of natural vegetation for cultivation of pineapple, ginger and turmeric along the slopes has an ill effect, which increases soil erosion in the Sylhet and in the hilly areas of Chittagong. These lands after 5-7 years of cultivation by this method totally degrade to an almost irreversible state, to the extent that it becomes practically unfit for further generations. Rubber plantations on more than 70 per cent of the slopes of Sylhet and Chittagong hills, leads to severe landslides during the heavy monsoon period.

The population pressure and scarcity of agricultural land has caused a heavy influx of settlers from the plainlands to the unprotected forestlands of Madhupur and Barind tracts and also to the northern piedmont plains. The topsoil of all these areas is either laid over infertile loamy soils of shallow depth or over heavy compact clays. Clearing of forestland for settlements and unscientific land management for agricultural use accelerate erosion of the topsoil with the runoff from high monsoon rain. In addition, the infertile heavy compact clay is exposed to the surface as a result of the removal of topsoil.

Faulty Irrigation

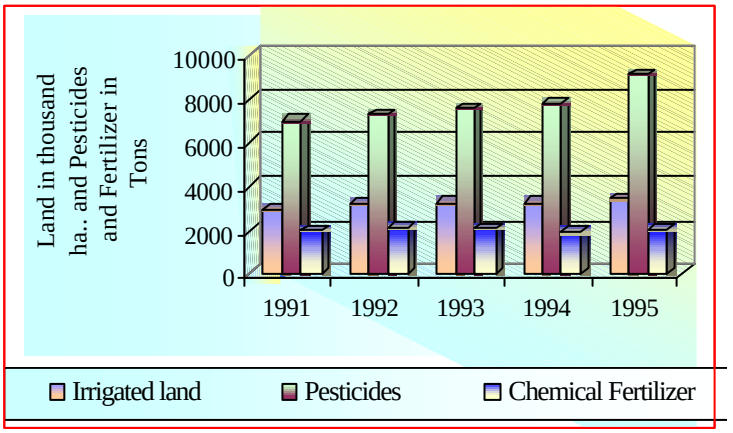
The availability of irrigation water can be a blessing or a curse depending upon how it is used. During the Fourth Five Year Plan (FFYP, 1990-94) a tremendous increase was made in the installation of Shallow Tubewells (STWs) and Deep Tubewells (DTWs) for groundwater irrigation. Most of this irrigation water is being used on relatively impermeable highlands of piedmont plain, meander floodplain and in terrace areas. A very small area is being irrigated in the *haor* basins by this irrigation system. In the highlands, the cropping pattern is mostly transplanted HYV *Boro/Aus* followed by rain-fed transplanted *Aman*, but in the basins broadcast *Aman* is grown followed the HYV *Boro/ Aus* varieties. As a result of this irrigation, the land remains inundated in most of the seasons, which keeps an adverse effect on soils because of continued oxygen deprivation in the sub-soils. Chemical changes of soil material forming toxic compounds for plants and constant percolation loss of essential nutrient elements including micronutrients and organic matter.

Imbalanced Fertilizer Use

The use of chemical fertilizers is directly linked to farming in irrigated lands. Three types of fertilizers such as Urea, Triple Supper Phosphate (TSP) and Muriate of Potash (MP) and four types of pesticides are commonly use in Bangladesh, which are insecticides, herbicides, fungicides, and rodenticides.

Figure 3.1.1 presents trends of irrigated land and use of chemical fertilizers and pesticides from 1991 to 1995. In 1991, the use of nitrogenous fertilizer alone accounted for about 67 per cent of the total fertilizer use, which rose to 88 per cent in 1995. Although there was no significant increase of total chemical fertilizer application. However, significant increase has been

Figure 3.1.1 Trend of Irrigated Land, Pesticide and Fertilizer Use



Source: BBS, 1994 and 1998

observed in use of pesticides, which has serious implication to quality of land and ecosystem.

Ploughpan

Transplanted rice covers the widest cultivated areas of Bangladesh, and is grown on medium highlands and medium lowlands. The soils are puddled in a wet condition for easy transplantation and to prevent percolation loss, but this destroys the soil structure. As a result of ploughing in wet condition, a compact 3-5 cm ploughpan is formed from the pressure of the plough, as well as from the pressure during the transplantation of seedlings (Rahman, 1991). This ploughpan impedes soil drainage, restricts root penetration to deeper levels and the movement of soil moisture from subsoil to the topsoil during the dry season. The resultant loss of soil structure makes the topsoil water resistant and hard, which makes tillage difficult and often makes it unfit for cultivating *Rabi* crops. Some people argue that if this compacted ploughpan method is not used, transplantation of rice will be affected, but this has not been shown to be true except in the shallow valleys of Madhupur and Barind tract.

Improper Use of Pesticides

Farmers of Bangladesh are using pesticides since 1957 and at present on an average of 12-15 thousand tons of pesticides is used every year. Insecticide accounts for about 90 per cent of the total consumed pesticide, and is used most for cultivating vegetables and *Rabi* crops (BBS, 1984 and 1998). Although pesticides are used at low levels still they are a cause of land degradation. The pesticides sprayed over standing crops ultimately contaminate the surrounding soil. Research findings show that pesticides applied at the rate of about one kilogram per hectare contaminates the topsoil to a depth of about 30 cm. The pesticides not only destroy harmful insects, but also destroy useful topsoil microbes, which eventually reduce the biological nutrient replenishment of the soil.

Over Exploitation of Biomass from the Agricultural Fields

One of the most important causes of land degradation specifically in the Barind tract, is over exploitation of biomass from cultivated fields (Hunt, 1984). The acute energy crisis in various areas leads to all available vegetation being scavenged for firewood and fodder. Due to the reduction of vegetative cover from this withdrawal of biomass silty loam topsoil over low permeability compact heavy clay is lost and topsoil gets inadequate water conservation capability. Therefore, there is considerable runoff due to heavy rainfall during the monsoon. This process of land degradation is also common in other highland and medium highland areas.

Unplanned Rural Infrastructure (Road, Embankment, FCD/I)

The rural roadways of the country have been constructed under *Upazila* or District programs through *Upazila* or *Union Parishads* (local level government). Therefore, the road alignment was subject to the influence of local politicians and influential people. A noteworthy feature of this alignment is that it follows the boundaries separating agricultural lands, rather than cutting through them. As a result, the actual length of the roads is often much longer than needed.

A significant part of the roadways constructed under the rural road network program fall within the floodplain, with a view to easy road communication during the monsoon season between village to village, villages to markets and villages to some industrial units. Therefore, the road heights had to be kept above flood level, for which a significant portion of agricultural land was acquired for the roadway and the borrow pits along the sides of the roads.

The main objectives of the development of flood control drainage and irrigation are to reduce flood hazard, facilitate agricultural productivity and the livelihood of rural households. The impacts of flood control, drainage and irrigation infrastructures have been given in detail in the Biodiversity section.

Urbanization

Urban development is necessary for economic growth, but the present process of urbanization in Bangladesh invariably reduces the amount of good agricultural land. Dhaka city has been growing at the expense of what were dense jackfruit and mango orchards in Savar, Gulshan, Banani and Uttara areas. The expansion of Khulna is reducing the coconut plantations of Phultala and Abhayanagar. These lands were not only good for horticulture, but also for *Aus*, *Transplanted Aman*, sugarcane and all kinds of dry land crops. The rapid urban growth of the past

two decades has mainly affected potentially triple croppable highlands.

Brickfields and Biomass Use

Brick making is a dry season activity that can be started as soon as the monsoon rain stops. Unfortunately, brick kilns are mostly situated on good agricultural land as brick manufacture needs silty clay loam to silty clay soils with good drainage conditions, which is turning good agricultural land into unproductive lands. Brick kilns are spread all over the country, and are degrading land. Moreover, over 50 per cent of the energy used for firing bricks comes from biomass.

Unplanned Industrial Development

Unplanned industrial development is of concern because it often encroaches on fertile land, and industrial effluents not only deteriorate the quality of soils but also affect fisheries. Despite the low level of industrialization, there are many pockets where effluent discharge cause serious harm to crops and fisheries. The rivers *Sitalakhya, Buriganga, Karnaphuli* and their banks are some of the many examples. There are areas of damage around or downstream of industrial units. Vast effluent discharge by ships has been identified as a major cause of pollution in the *Passur* river downstream of Mongla port. This has affected both forest and coastal lands in the Sunderbans (UNDP, 1989). The distribution of the most polluting industrial units and their subsequent impacts on water and land are given in detail in the Water Pollution and Scarcity section of the report.

In addition to polluting both water and land, most industrial units have acquired or bought more land than is required. This can be seen in all the district industrial estates, for example, on the other side of the *Sitalakhya* river along the Dhaka-Chittagong road. In Khulna, a big area has been acquired and part of it has been utilized for industrial units and part remains unutilized. Planned industrialization and land zoning would be appropriate measures to combat this type of land degradation.

Mining of Sand and Gravels from Agricultural Land

Mining of sand from agricultural land is common along the eastern side of the Dhaka-Chittagong road, from Comilla to near Sitakunda, and in the northern piedmont areas of northern Netrokona District. Farmers tend to enjoy the immediate monetary benefit and lease out their land for extracting sand, which is used in glass manufacturing industries or as building material. First, 2-3 feet of topsoil are removed from the land and dumped anywhere available near the site. Sand is extracted to a greater depth. Once the sand is extracted, the new tenant abandons the site and no one is responsible for making the land productive again (Rahman, 1991). The damage is two fold - the land purchased for dumping topsoil is used unproductively, and the land from where sand is extracted remains unutilized for many years.

Extraction of pebbles from 2-3 feet below the surface of agricultural land is a common phenomenon in the northern part of greater Dinajpur and Rangpur Districts. There are many similar examples of wasteful use of land by businessmen. Farmers lease out or sell their land at higher prices for immediate gain, but in fact a portion of farmland is lost from their descendents, and eventually there is an environmental loss to the nation.

Land Ownership and Tenure

The present land tenure and commercial approaches do not provide security to farmers. Since Bangladesh is mostly an alluvial delta, there are land formations of different ages from very recent to old alluvium. Soil improvement for sustained crop production in new alluvial land is a long-term process. But the short-term leases that are common do not provide an incentive to farmers to engage in long-term land improvement.

There are many other such related problems. Big farmers cannot manage all their parcels of land by themselves. Therefore, in almost all cases owners retain the irrigable lands (even if they cannot manage them all themselves) and lease out the relatively less productive, non-irrigable land. The practice has two adverse effects on agricultural land. Firstly, the landlord's attitude that the land is less valuable has a negative effect psychologically on the sharecropper in terms of management of the land. Secondly, the sharecropper calculates his short-term benefit when farming the land, rather than thinking of the future for making the land more productive than its present state.

3.1.2.2 Waterborne Land Degradation

Riverbank Erosion and Sedimentation

The most devastating form of waterborne land degradation in Bangladesh is riverbank erosion. The

active floodplains of the *Ganges*, the *Brahmaputra-Jamuna*, the *Tista* and the *Meghna* rivers are most susceptible to riverbank erosion. Moreover, small rivers, particularly in eastern Bangladesh, also erode land, although to a relatively lesser extent than the big rivers.

There are many factors that may be responsible for riverbank erosion. The unique, natural geographic setting, the behavior of an alluvial channel, together with characteristics of the tropical monsoon climate, are mainly responsible for these ravages. An enormous volume of water comes from the melting of ice in the Himalayan range. Besides natural processes, human activities both up and downstream, mainly irrational use of forest and other natural resources, cause further deterioration of the situation (Islam, 1986). The whole combination of factors creates an ideal situation for producing devastating floods, which cause bank erosion and sedimentation.

In the southern part of the country, the riverbank erosions are also severe. Hatia, Sandwip and Bhola islands are severely prone to recurrent bank erosion. The amount of water and sediment carried in the *Ganges-Brahmaputra-Meghna* (GBM) river system is given in detail in the Water Pollution and Scarcity sections of the report.

Deposition of Sandy Over-wash on Agricultural Land

Deposition of sandy materials on agricultural land is frequent in the lower part of the piedmont areas of greater Mymensingh and valleys of Sylhet and Chittagong Hill Tracts. This is the net result of deforestation in the hills of the upper catchment areas. During the monsoon season, when heavy rainfall occurs in the upper hill areas, it causes flash floods in the lower plains. With the runoff, the water carries sandy sediments that spread over agricultural lands. In the areas of the lower foothills, deposits of sandy materials go up to even a few meters, which compels farmers to abandon such land for agriculture purposes.

Land degradation by deposition of sandy materials on agricultural land also occurs when there is a breach of embankments and the materials spread over adjoining agricultural land. This kind of local land degradation often occurs in many riverbank embankments, in the Flood Control and Drainage (FCD) and Flood Control Drainage and Irrigation (FCDI) projects. Many of the Flood Control projects that could not be completed in time resulted in spillover from unfinished polders onto adjoining fields during the monsoon season.

Salinity

Land with saline soil occurs in the young *Meghna* estuary floodplain and in the southern part of the *Ganges* tidal floodplain. Salinity in the coastal areas developed due to continuous accumulation of salt from tidal flooding and salt removal by leaching or washing by rain or inadequate freshwater flushing. Salinity during the dry season mainly develops from the capillary rise of brackish groundwater to the surface. Total salt affected area of the coastal area is 0.83 million hectares, detail of which is given in Table 3.1.2.

Table 3.1.2 Soil salinity distribution from August to April

Month	Area under different soil salinity class (in thousand hectares)				
	S0	S1	S2	S3	S4
August	287.4	426.4	75.8	41.9	2.0
September	258.6	433.9	93.1	45.9	2.0
October	244.3	426.9	110.4	47.9	4.0
November	215.5	391.7	170.4	45.9	11.0
December	201.2	406.0	162.4	51.9	12.0
January	201.2	384.7	179.8	55.8	12.0
February	172.4	413.5	175.8	57.8	14.0
March	115.0	428.3	210.5	63.8	16.0
April	0.0	287.4	426.4	79.8	39.9

Source: Karim, 1990

It is reported that upstream withdrawal of the *Ganges* water has significantly reduced the freshwater discharge, and hence salinity is encroaching gradually deeper into the mainland. As a result, farmlands are being degraded by increased salinity, non-availability of groundwater for irrigation, industry and domestic need.

3.1.3 STATE OF LAND DEGRADATION

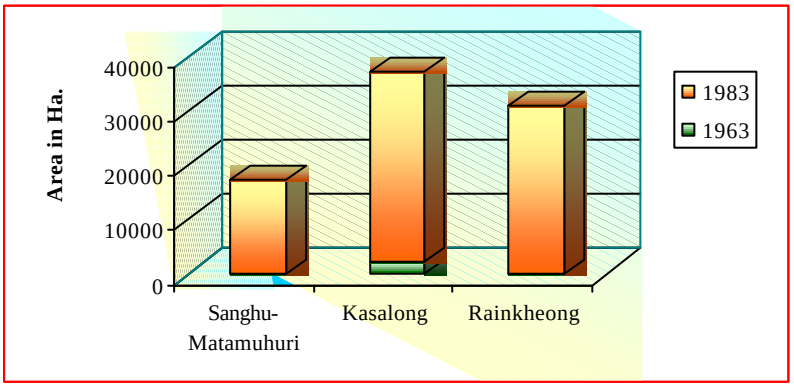
Comprehensive studies are lacking on the issue of land degradation in Bangladesh. The country needs further research and studies to precisely delimit the areas affected by, or vulnerable to land degradation. There are inadequate statistics on how much area is annually brought under shifting cultivation in the Chittagong Hill Tracts. Statistics on loss of forestlands in Madhupur, Barind and Piedmont

plains for agriculture, and other uses are also insufficient. There are few studies on the wastelands created by abandoned brick fields, and associated abandoned roads, but a good amount of land once regarded as good agricultural land has now turned unproductive. Statistics on irrigated area and uses of different pesticides are available, but studies on the extent of land degradation are lacking. The information is insufficient to make a comprehensive nationwide assessment on land degradation. However, a number of case studies are available, which do give an idea of the condition of land and the state of land degradation. A few of these examples are described below.

A view of deforestation

A few case studies have indicated that *Jhum* cultivation has been intensified, and has shown an increasing trend over the past few decades. Figure 3.1.2 shows the changing status of *Jhum* cultivation in three forest ranges. An evaluation of the Sanghu-Matamuhuri reserve forest indicated that shifting cultivation, which was practically non-existent in 1961, accounted for 17,135 ha in 1984, which is about 23 per cent of the total area. In Kasalong, 2,096 ha were identified as *Jhum* areas in 1963, whereas in 1983 the area increased sharply to 35,079 ha. In Rainkheong, in 1963 *Jhum* area was only 14 ha, which increased to 30,838 ha in 1983 (Rahman, 1991).

Figure 3.12 Changes of *Jhum* Cultivated Area in Three Forest Ranges



Source: Rahman, 1991

Landsat imagery indicates a definite change in vegetative cover and soil moisture in the Barind Tract, particularly the Western Barind. It resembles an arid zone during the months of March-April, although once moderately sized forest, bushes and shrubs were visible (Hunt, 1984).

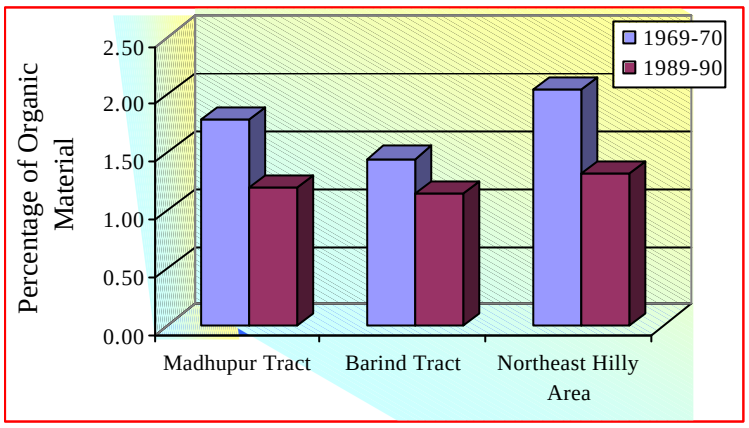
Erosion of topsoil in the hill districts has increased, and 17 per cent of the soil resources have deteriorated between 1964 and 1985 (IUCN, 1991).

Topsoil erosion per unit area depends on the type of land cover and land use practices. It was found that topsoil erosion rate is 2.7 to 7.2 tons per ha per annum in the mixed forest-covered land. On the other hand, per hectare erosion goes up to 120 tons in the deforested hill slopes (Shahid, 1994). A study in Khagrachari, Rangamati and Bandarban area on topsoil erosion revealed that topsoil erosion ranges from 100 to 120 tons per ha annually (Farid *et. al.*, 1992).

The amount of organic matter in the soil is one of the best indicators representing soil quality. The concentration of soil organic materials in the country has been deteriorating over the last few decades. Now over 50 per cent of the agricultural land is below the critical level. The highest deterioration of organic materials has been found in the Barind Tract, Madhupur Tract, Himalayan Foothill areas, the floodplains of *Tista*, *Karatoya* and *Bangali*, and in the northeast hilly region. Moderate deterioration of organic materials has been observed in medium highlands of the rivers *Tista*, the *Jamuna* and in the *Ganges* floodplain (Karim *et. al.*, 1994). Figure 3.1.3 shows changes of organic materials from 1969-70 to 1989-90.

The Soil Resources Development Institute (SRDI) has analyzed soil samples, and found that nitrogen deficiency is common all over the country. The Sylhet *haor* areas, *Surma-Kushiyara* floodplain, northeast hilly area and Madhupur Tract have a noticeably intense deficiency of Phosphorus. Deficiency of other chemical substances has also been noticed in other parts of the country.

Figure 3.1.3 Changes in Organic Matters from 1969-70 to 1989-90



Source: Karim et. al., 1994

As shown in Table 3.1.3, the level of organic matter in the soil of Bangladesh is very low. About 45 per cent of the net cultivable area (NCA) of the country has less than 1 per cent organic matter content.

Accurate assessment of the salt affected area in the coastal region is very difficult, as the level of salinity varies according to season and year. However, it is clear from different sources that the salinity level of both surface water and soil has increased over the last decade. Saline affected areas in the coastal district have increased to about 3.05 million in 1995 from 0.83 million ha in 1966-75 (Karim *et. al.*, 1990 and SRDI, 1997). Noteworthy changes occurred in the categories which lies above 8 dS/m. During the period of 1966-75, a very small amount of area was under the category of more than 8 dS/m, which became intense in 1995. Changes of saline affected areas are shown in Figure 3.1.4 in detail.

Studies on riverbank erosion have shown that the overall erosion is higher than sedimentation along the riverbanks in the *Brahmaputra-Jamuna* river system, and that there is net accretion in the *Meghna* estuary starting from Chandpur.

The "Riverbank Erosion Impact Study", conducted jointly by Jahangirnagar University and University of Manitoba during 1984-87 at three places, namely, *Chilmari* (Rangpur), *Kazipur* (Serajgonj) and *Bhola*, found that about 15,750 ha of land eroded over the period of 1961 to 1981, while only about 4,600 ha land have been formed through accretion (Elahi, 1985).

Environment and GIS Support Project for Water Sector Planning and Delft Hydraulics conducted a study on behalf of Water Resource Planning Organisation (WARPO) on "Morphological Dynamics of the *Brahmaputra-Jamuna* River" from 1973 to 1996, using remote sensing images. Their study showed a total of 73,552 ha of land eroded during the period of 1973 to 1996, while only 10,628 ha of land have been formed by accretion.

Analysis of remote sensing data for the period of 1993 to 1998 measured the net accretion in the *Meghna* estuary, starting from Chandpur towards the Bay of Bengal (MES, 1999). Up to 1984, erosion was higher than the accretion, but major accretion occurred during the period 1984-1990 and 1993-1996. The accretion and erosion over the years amounts to 107,863 and 87,967 ha, respectively. Thus the net accretion in the *Meghna* is about 19,896 ha. Figure 3.1.5 presents erosion and accretion in the *Brahmaputra-Jamuna* and *Meghna* river systems.

Based on currently available information and data, it appears that all agricultural lands have degraded to different extents. From this about 8 million ha show fertility decline and deficiency of nutrients,

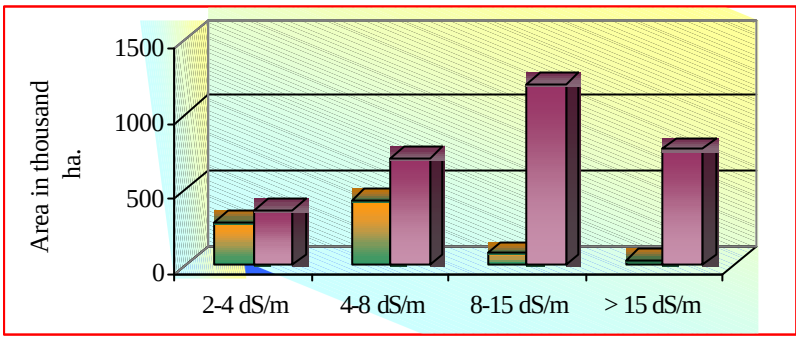
Table 3.1.3 Organic Matter Status of Bangladesh Soils

Class of organic matter	Main Locations	Total Area (Mha)	% of NCA
Very Low (<1.0 %)	Dinajpur, Sherpur, Jamalpur, Tangail, Nawabganj, Rahshahi, Pabna, Kushtia, Bogra, Naogaon, Rangpur, Khagrachari, Bandarban and Chittagong	4.05	44.5
Low (1.0-1.7 %)	Adjoining area of Tista, Dharlus, Chandpur, Lakshimipur, Noakhali, Bhola, Barisal, Patuakhali, Narsingdi and Dhaka	1.56	17.1
Medium (1.7-3.5 %)	Sirajganj, Mymensingh, Kishoreganj, Sherpur, Jamalpur, Sylhet, Moulvibazar, Feni and Cox's Bazar	1.94	21.3
High (>3.5 %)	Panchaghar, Natore, Naogaon, Khulna, Satkhira, Madaripur, Gopalganj, Munshiganj, Habiganj, Sunamganj and Netrokina	1.56	17.1

Source: BARC, 1999

which has significant implication on production (Karim and Iqbal, 2000). Based on the agricultural suitability, different levels of degraded land have been categorized further as light, moderate and strong. The degraded terrain has reduced suitability for high yielding agricultural productivity, but is suitable for local farming systems. Restoration to full productivity is possible through modifications of management system. When original biotic functions are more or less largely intact and production loss is about 5-10 per cent, the degradation is termed light; for the moderate class the productivity loss is about 20-25 per cent, but it is still suitable for use in local farming systems; major improvements are required to restore productivity of the strongly degraded class, as the original biological functions are partially destroyed. Various types of land degradation are presented in Table 3.1.4.

Figure 3.1.4 Salt Affected Area in 1966-75 and 1997 (average)



Source: Karim et. al., 1990 and SRDI, 1997

During the last few years, thousands of kilometers of rural roads have been constructed under a "Food for Work Program". Current data on the total length of roads constructed in each *Union* or *Upazila*, and how much land has been acquired for this purpose is not available. An inventory is in progress detailing the types and status of these roads by CARE Bangladesh and Local Government Engineering Department (LGED).

Data on the exact amount of agricultural and forest land transformed due to urbanization is scanty, but a few examples of this phenomenon are obvious. Most of the flood-free land to the north and west of Dhaka City is among the best horticultural land in the country, but has now gone under extensive of urbanization. The most striking example is the Bangladesh Agricultural Development Corporation (BADC) agricultural estate at Kashimpur. The Kashimpur Agricultural Estate of BADC was established on very good agricultural land to meet the demand for vegetables in Dhaka city, but now it has effectively turned into urban land.

As for another example, the acquisition of 300 ha of land for Rajshahi University, of which only 120 ha have been utilized so far, is a misuse or abuse of scarce land of that region. Again, acquisition of 40 ha of land in Faridpur for the River Research Institute was done at the time when there was already an alarming condition of land scarcity, perceived both by the Government, as well as the public. There are many more examples scattered all over the country such as abandoned airstrips constructed originally for aerial plant protection services, *union* fertilizer storage sheds, etc. Large quantities of good farmland in almost every *upazila* are being used for construction of office buildings, shopping complexes, houses, schools, colleges, universities, hospitals and health centers, although there are alternative less agriculturally important lands available nearby.

3.1.4 IMPACTS OF LAND DEGRADATION

Land degradation is not merely a matter of physical loss of land or quality, but has inter-related impacts. For example, riverbank erosion is more than just a physical phenomenon of land degradation. For the poor, loss of crucial land resources affects them economically, socially, and psychologically. In

Figure 3.1.5 Erosion and Accretion in *Brahmaputra-Jamuna* and Lower *Meghna*

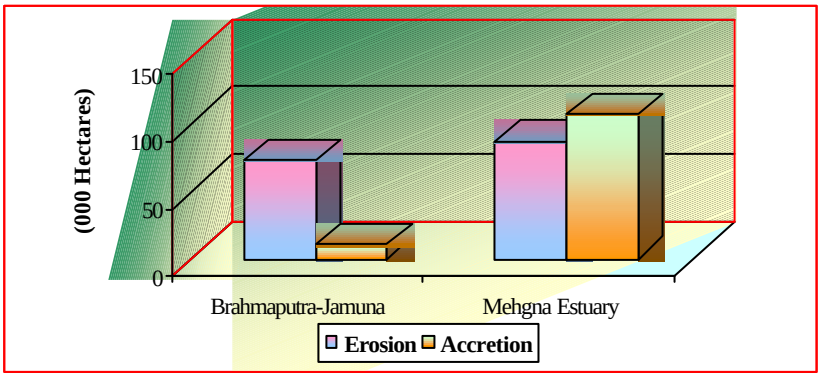


Table 3.1.4 Types and Extent of Land Degradation

Type of Land Degradation	Area under different degrees of degradation (Mha.)			Total Area (Mha)
	Light	Light	Light	
Water erosion	0.1	0.3	1.3	1.7
Riverbank erosion	-	1.7	-	1.7
Soil fertility decline	3.8	4.2	-	8.0
P deficient (for HYV rice)	5.3	3.2	-	8.5
P deficient (for Upland Crops)	3.1	2.5	-	5.6
K deficient (for HYV rice)	4.0	3.4	-	7.4
K deficient (for Upland Crops)	2.1	5.4	-	7.5
S deficient (for HYV rice)	4.4	3.3	-	7.7
S deficient (for Upland Crops)	4.1	4.6	-	8.7
Soil Organic Matter Depletion	1.94	1.56	4.05	7.55
Water logging	0.69	0.008	-	0.7
Salinization	0.29	0.43	0.12	0.84
Pan formation	-	2.82	-	2.82
Acidification	-	0.06	-	0.06
Active floodplain	-	-	-	1.53
Deforestation	-	0.3	-	0.3
Barind	-	-	-	0.773

Source: Karim and Iqbal, 2000

particular, loss of land leaves rural people declassed, and alienated from the main stream of society and culture that is based on land as a measure of wealth. Extensive erosion of riverbanks renders thousands of people homeless every year, and compels them to leave the affected areas in search of new settlements. It has been estimated that each year over one million people are affected by riverbank erosion (REIS, l985).

Waterborne land degradation of various types in a locality is often immediately noticeable and evident to the people. However, degradation caused by direct human interference is often a slow process and the community does not realize the effect immediately. They keep themselves satisfied with the immediate gain. In-depth impact studies on various aspects of land degradation are inadequate at the country level. But the general consensus are agricultural yield reduction and displacement of human populations resulting from degradation of soil quality and land, which also have social and economic implications.

A study by Pike and Yaho showed declining trend of the output from high yielding rice varieties, almost without exception, in all areas due to continuous waterlogging in the rice fields. The field personnel of the Directorate of Agricultural Extension (DAE) of the Ministry of Agriculture have also authenticated these findings. Most of the farmers who cultivate a land for more than 5 years continuously with irrigated HYV rice complain of a considerable decline in land productivity with time. At present, they are using higher doses of fertilizers and pesticides to get the same yield they got in the earlier years.

In addition to lowering the inherent soil fertility, continuous waterlogging also adversely affects land by:

- Spreading hydrophytic soil-borne pests and diseases, which become difficult to combat or eradicate as fields remain waterlogged continuously, season after season;
- Decreasing the bearing capacity of soils, particularly in some deep silty clay loam soils, making it difficult for farmers to work it.

Mono-cropping patterns in the country are also responsible for the deterioration of soil quality and productivity of land due to intense use of chemical

fertilizers and pesticides, and deteriorating soil quality (Karim *et. al.*, 1998). This is emerging as an important issue regarding sustainability of the cropping pattern and productivity. Already, Bangladesh is experiencing a decline or stagnation in the yield of many crops. According to Bangladesh Rice Research Institute (BRRI), 30 cropping patterns observed in 1997 of which 28 cropping patterns were found to have paddy as a component. The noteworthy feature of the findings were that nine all-rice patterns occupied 60 per cent of the total area covered by 30 cropping patterns (Karim and Iqbal, 2000). The deleterious effects of continuous wet-culture of rice were seen in the declining yields, and reduced availability of soil nutrients, particularly sulphur and zinc. There is also a decrease in soil organic content, due to decreasing practice trend in legume, green manure and jute-based cropping.

Salinity is a problem for cropping in the dry season. But in pre-monsoon and monsoon months, salinity is no longer a limiting factor. As a result, it appears to be possible to cultivate *Aman* varieties of rice in those areas between late May and September. However, even in such cases, the expected yield reduces to a certain degree depending on the soil salinity concentration (Karim *et. al.*, 1990).

Shifting and hill cultivation in Chittagong district not only degrade land productivity, but also causes excess runoff. This accelerates soil erosion and causes flash floods. The additional effect, other than loss of the sloping land, is that soil particles from erosion move down the slope, and are deposited on the riverbed, in the adjoining basins and over flat alluvial land. The beds of rivers and deep basins have been raised, which has affected drainage condition, and infertile soil material is spread over flat alluvial land burying fertile topsoil. Kaptai reservoir is now severely threatened by slow rising of the bed due to deposition of sediments coming in with the river water as a results of shifting cultivation in the surrounding hills. The siltation rate of the Kaptai reservoir is given in the Water Pollution and Scarcity chapters in detail. These kinds of land degradation phenomenon are also common in the northern piedmont areas, and foothills of Sylhet and Comilla.

The most adverse effect on the land caused by the rural road network is drainage congestion. Most of these roads have inadequate number of culverts, because the authority in charge of construction often lacked the expertise on drainage needs and also had limited technical capability to determine the sites where culverts were needed. As a consequence, apart from the creation of man-made floods, during heavy rainfall the floodwater recedes slowly, so that agricultural land remains waterlogged for a longer time. This limits the cultivation of early high priced *Rabi* crops such as mustard, lentil, wheat, etc. Now farmers in the meander floodplain areas often complain that in their fields *"Joo"*, i.e., the optimum moisture required for sowing and germination, is present much later than a few years ago. Due to this, ploughing of the land for *Rabi* crops is delayed. Farmers are now compelled to grow late *Rabi* crops such as *Kheshari*.

There is no doubt that loss of land due to riverbank erosion causes not only morphological changes in the land, but also in the socio-economic condition of the affected people. A study by the Centre for Urban Studies (CUS) shows that riverbank erosion lad to displace people losing stability in their lives and social status (CUS, 1988). The reality is that displaced people suffer terribly not only from loss of their land and housing, but also from a lack of psychological and social assimilation in the new places they settle. They are usually regarded as unwanted wherever they settle either in the cities or in new rural areas.

When riverbank erosion claims land and homesteads, the affected people have no alternative, but to move in search of new land and shelter. Many of them migrate to cities and are absorbed in urban informal-sector activities. The presence of hundreds of uprooted families on the 86 Km stretch of the BWDB embankment from Kazipur to Chouhali, via Serajgonj, testifies the magnitude of the riverbank erosion problem in the mid *Jamuna* floodplain. According to an estimate, about 8,000 households have become squatters on the embankment (Zaman and Babla, 1985).

Besides its social and environmental aspects, the economic implications of land degradation are tremendous. An assessment has been made in terms of production loss of crops and additional agricultural input necessary to maintain soil nutrients. It was found that the total economic cost of land degradation exceeds to 2 billion US dollars per year, as presented in detail in Table 3.1.5.

The presence of arsenic in the groundwater has been noticed in Bangladesh, and concerns over the use of

Table 3.1.5 Estimated Cost of Land Degradation in Bangladesh

Nature of Land Degradation	Physical Quantity of Loss Output	Amount (mt/yr.)	Cost (Million US $/yr.)
Water Erosion	Cereal Production Loss	1.06	140.72
	Nutrient Loss	1.44	544.18
Fertility Decline	Cereal Production Loss	4.27	566.84
	Additional Agricultural Inputs	1.22	461.04
Salinity	Production Loss	4.42	586.75
Acidification	Production Loss	0.09	11.95

Source: BARC, 1999

arsenic contaminated groundwater for irrigation have emerged. It is yet to establish whether arsenic has any implication on yield reduction or whether it is entering the food chain, which would have serious health implications.

3.1.5 RESPONSES

Many human activities are based on land, and therefore are influenced by unwise and improper use of land resources. A number of stakeholders are involved in land use and land management, from both the government and private sectors. The demands of a growing population is the prime driving force that lead to deterioration of the quality and quantity of soil and land. A number of policy measures and practices have been initiated over the last decade to mitigate these. However, implementation of these measures are not adequate to combat land degradation.

The most important policy measure that is required for addressing land degradation is an integrated land use policy with respect to agriculture, industry and environment. Noting the importance of such a land use policy, the Government of Bangladesh has already made some progresses in this direction. A draft land use policy has been prepared, which is under discussion for government's approval.

3.1.5.1 Institutions

A number of institutions are involved in addressing issues related to land and preventing land degradation, ranging from the legal to management. The Ministry of Land particularly deals with legal aspects of land through their different wings. They are also associated with the land acquisition process for development work. The Ministry of Agriculture through the Bangladesh Agricultural Research Council (BARC) deals with productivity aspects of land. Under the same ministry, the Department of Agricultural Extension (DAE) undertakes extension of the research outcomes of the institutes mentioned above. The Department of Environment (DoE) under the Ministry of Environment and Forest (MoEF) deals with aspects of land pollution.

3.1.5.2 Major Policy Responses

Draft Land Use Policy

A strategy for sustainable development of land resources require a comprehensive National Land Use Policy (NLUP). This needs to be concerned to introduce multi-disciplinary and inter-sectoral approaches to ensure optimum use of land, protect land from degradation, reclaim unutilized or degraded land for suitable use and improve land resources for future generations. The Ministry of Land has taken the initiative and prepared a Draft Land Use Policy for Bangladesh.

Some salient features of the Draft Land Use Policy are as follows;

- ***Land and Agriculture***: Agricultural land should be used as per national agricultural policy, and acquisition of existing and potential irrigated land should be stopped completely. Existing cropland cannot be converted to other non-agricultural uses. In the case of unavailability of land for non-agricultural uses, less productive land can be acquired.
- ***Land and Forest***: Extensive reforestation is needed to enhance the overall environmental condition of the country. It is necessary to implement Environment Policy 1992 and Forest Policy 1994.
- ***Land and Settlement***: Unplanned rural settlement should be addressed by introducing a comprehensive housing policy, incorporating city corporations, metropolitan areas and *upazilas*. Local Government can pay a vital role to minimize transformation of good agricultural land to settlement.

- ***Land and Industry***: Industrial development is necessary for development, and Bangladesh obviously needs it. Land acquired by the Bangladesh Small and Cottage Industries Corporation (BSCIC) should be used properly, and new industry should be discouraged within a range of 10 km. As most of the industries were found very close to major roads, it is also proposed that 500 meters of land on both sides of the main road should be dedicated to industrial development.
- ***Land and Wetland***: Highlighting the importance of wetlands, advocate for implementing Fisheries policy as a basis for wetland use.
- ***Land and Tea and Rubber Garden***: Existing land under tea and rubber gardens cannot be used for other purposes, and valuable trees cannot be harvested in an indiscriminate manner.

In addition, the Land Use Policy also highlights other uses of land for different social and cultural purposes. Certified land ownership is one of the important aspects of the land use policy aiming at reduction of ownership-related problems and crime. For implementing the land use policy successfully, it emphasizes mass awareness programs for the general population and government administration.

Agriculture Policy 1999

Very recently the government has approved the Agricultural Policy of 1999. The major thrust of the policy is increased food production, and to address food and nutritional insecurity issues through self-sufficiency. It emphasizes environment-friendly, sustainable agriculture, and strengthening of agro-forestry programs of government and non-government organizations. It also highlights the need for frontier research, for example, on biotechnology and use of GIS based information.

Integrated Pest Management Policy, 2000

Integrated Pest Management (IPM) activities started in 1981, and have already passed through several phases of research and extension. IPM has an immense contribution in reducing the use of pesticides for crop production. Results show that it has the potential to increase crop production directly and yet contaminate soil very little. Considering these benefits of IPM, the Government has initiated the National Integrated Pest Management Policy in 2000.

Integrated Plant Nutrient System (IPNS)

Integrated Plant Nutrient System (IPNS) is a new concept to combat land degradation, particularly to address degradation of soil and land quality, since it uses a need-based nutrient application. In IPNS, the amount of nutrient application is specifically determined through diagnostic testing and estimation of the inherent nutrient status. Then there is a recommended application of a mix of organic and inorganic nutrients, including use of Biological Nitrogen Fixation (BNF). This system ensures the actual need for application of agricultural inputs and avoid excess application. Proper extension and large-scale adoption of this concept will reduce land degradation in terms of soil quality, land productivity loss and pollution by nutrients and nutrient availability (Iqbal, 2000).

There are other national policies and measures that have indirect positive impacts on combating land degradation. The noteworthy policies are the National Environment Policy, National Environment Conservation Act and Rules, National Forestry Policy, National Conservation Strategies, and the Strategic Plan for National Agricultural Research.

3.1.6 OPTIONS AND MEASURES NEED TO COMBAT LAND DEGRADATION

A comprehensive study at the country level on land degradation, covering all its aspects ranging from the physical to economic, is absent. However, it is clear that the quality of land has deteriorated, and its impacts are visible. Over the last decade, crop yield has declined due to deterioration of physical and chemical properties of land and soil. It would be useful to establish a baseline survey on which future monitoring and assessment of further deterioration or improvement could be based.

The country has a number of policies to deal with land degradation, but with limited implementation. The existing polices must be implemented, and a number of new activities should be undertaken in the immediate future to address land degradation. Research and its extension to practice are the most important steps that should start without delay. Brief descriptions of future needs, along with potential local stakeholders to undertake solving them, are presented in Table 3.1.6. A strategy is also required to obtain support from international agencies.

Table 3.1.6 Options and Measures to Arrest Further Land Degradation and Improve the Existing Situation.

Option	Outcome	Actors
Policy		
National Land Use Policy: *Comprehensiveness, long-term vision, people's participation*	Land Zoning will help sustainable land management and its development for different uses, utilization in the newly accreted fragile land in the estuary	Ministry of Land, Ministry of Agriculture, Ministry of Industry, Ministry of Environment and Forest, Ministry of Water Resources, Business community
Appropriate Cropping Pattern: *Adjustment of cropping patterns on a large scale incorporating legume/green manure crops and crop diversification*	Balance cropping patterns. Improvement of organic content of soil and sustainable agricultural production	Ministry of Agriculture along with its different wings (BARC, NARS, DAE, etc.)
Research		
Assessment and Monitoring: *Survey of the present state of land degradation and impacts, cropping and land capability*	Reflection of real situation of land degradation and extent of its severity will help to identify future course of actions required for addressing land degradation	Ministry of Agriculture along with its different wings (BARC, NARS, DAE, SRDI, etc.), Ministry of Environment and Forest, Ministry of Water Resources, Ministry of Planning
Restoration of Degraded Land: *Introduction of appropriate cropping patterns, introduction of salt tolerant varieties, soil conservation, and watershed management*	Improvement of soil quality, crop production in saline soil and restrict land degradation.	Ministry of Agriculture along with its different wings (BARC, NARS, DAE, etc.), Ministry of Environment and Forest, Ministry of Water Resources
Watershed Management: *Catchment based watershed management*	Arrest erosion in the hill slopes and improve gradual siltation in the floodplain	Ministry of Water Resources, Ministry of Agriculture Ministry of LGRD and Ministry of Environment and Forest
Extension		
Balanced use of Chemical Fertilizer and Adoption of IPNS	Improvement of soil quality, increase crop production and restrict land degradation	Ministry of Agriculture along with its different wings (BARC, NARS, DAE, etc.)
Mass Awareness and Motivation	Improvement of soil quality, increase crop production and restrict land degradation	Ministry of Agriculture along with its different wings (BARC, NARS, DAE, SRDI, etc.), Ministry of Information

Source: SoE Study Team

3.1.7 CONCLUSION

Land is an important natural resource that has direct and indirect linkages with human being in every sense such as production system, economic activities, and social and cultural more. The country has a reasonably good number of policies to combat land degradation, but they are not fully implemented yet.

There are two major constraints in preventing land degradation. The first one is the high population pressure on land, especially in the central, west and northwest parts of the country. In these regions, the exploitation of biomass due to a prevalent energy crisis appears to have exceeded the carrying capacity of the land, and led to encroachment on natural forests in the Chittagong Hill Tracts and Madhupur. The second constraint is the absence of a comprehensive national land use policy. However, a draft land use policy has emerged as the follow-up program of the NEMAP, and is in place for wider discussion and government approvals. It needs to be emphasized that a plan to prevent land degradation must begin with strengthening of knowledge regarding the susceptible areas.

There is a wide gap between awareness of land degradation problems and actions necessary to combat them. Land degradation in many areas goes unnoticed from generation to generation, and therefore the concept of land resource conservation fails to attract politicians and planners. The scientists are worried about and warning everyone on the use of continuous irrigation, application of chemical fertilizers, use of good agricultural land for non-agricultural purposes, the lack of an integrated approach towards construction of rural road networks, problems with coastal polders, conversion of ecologically rich wetlands for single *Boro* crop production, and so on. However, they are often disregarded and the common attitudes of the common people is that they know about their land.

Politicians, decision makers and planners often do not see the land as the scientists do. The scientists see the land as a natural body, with its own delicate balance, and that problems and consequences can arise from its mistreatment. Farmers in general, particularly small farmers, are suspicious of innovations and are not easily convinced to use scientific methods, which would benefit them from resource conservation programs in the long run.

Present knowledge about the present status of the land degradation process and its level of impacts on national development and rural livelihood system is inadequate, and definitely requires further investigation and research. The potentiality of preventing further degradation in the future is uncertain, as the country suffers from a lack of innovative technology and adoption of recent technologies from outside the country, a low level of education and social awareness, and limited enforcement of laws and regulations. Therefore, in order to combat land degradation and to attain sustainable land management and development, it is very urgent to build institutional capacity to conduct field level research and apply the results through extension programs along with enabling policy makers to take necessary decision and to undertake appropriate mitigation measures.

Reference

BARC (1997) Land Degradation Situation in Bangladesh. Soil Division, Bangladesh Agricultural Research Council. Dhaka, Bangladesh.

BBS (1994) *Statistical Year Book of Bangladesh*, Bangladesh Bureau of Statistic, Ministry of Planning, Dhaka, Bangladesh.

BBS (1998) *Statistical Year Book of Bangladesh*, Bangladesh Bureau of Statistic, Ministry of Planning, Dhaka, Bangladesh.

CUS (1988) *Composite Score map of Socio- economic Development of Bangladesh by Upazila*, Center for Urban Studies, Dhaka University, Dhaka, Bangladesh.

Elahi, K.M. (1985) Riverbank Erosion and Floods in Bangladesh: Need for Inventory and Planning, In *REIS*, Bulletin No. 2.

Farid, A.T., Iqbal, A. and Karim, Z. (1992) Soil Erosion in the Chittagong Hill Tracts and Its Impact on Nutrient Status of Soils, Bangladesh Journal of Soil Science, Vol. 23 (1&2), Page 92-101.

Hunt, J.M. (1984) *Area Development of Barind Tract*, Dhaka, Bangladesh.

Iqbal, A. (2000) The Bangladesh National Report on the Land, Water and Plant Nutrition in Bangladesh, *Regional Workshop on Land Resources Information System in Asia*, Manila, Philippines.

Islam, M.N. (1986) Alternative Adjustment to Natural Hazards; Implication for Bangladesh, *Presidential Address at the 11th Annual Bangladesh Science Conference*, Rajshahi, Bangladesh.

IUCN (1991) *National Conservation Strategy of Bangladesh (Draft)*, International Union for Conservation of Nature and Natural Resources; Ministry of Environment and Forest, GoB, Dhaka, Bangladesh. P. 83.

Karim, Z., Hussain, S.G. and Ahmed, M. (1990) *Salinity problems and crops intensification in the coastal region of Bangladesh*, Bangladesh Agricultural Research Council, Dhaka, Bangladesh.

Karim, Z., Mia, M.M.U. and Razia, S. (1994) Fertilizer in the National Economy and Sustainable Environmental Development, *Asia Pacific Journal Environment and Development*, 1 (2): 48-67.

Karim, Z., Hussain, S.G. and Rahman, M. (1998) *Chemical Fertilizer for Increase Crop Production Poses on Threat to Soil Pollution in Bangladesh*, Bangladesh Agricultural Research Council, Dhaka, Bangladesh (unpublished).

Karim, Z and Iqbal, M.A. (ed.) (2000) *Impact of Land Degradation in Bangladesh: Changing Scenario in Agricultural Land Use*, Bangladesh Agricultural Research Council, Dhaka, Bangladesh, (in press).

MES (1999) Technical Note 023. Meghna Estuary Study. Dhaka Bangladesh.

Pike, J.G. and Yano, T. (1986) *Investigation of Lands with Declining and Stagnating Productivity Report*, Dhaka, Bangladesh.

Rahman, M.R. (1991) *Towards Sustainable Development Land Resources in Bangladesh*, Ministry of Environment & Forest and National Conservation Strategy Secretariat, Bangladesh Agricultural Resource Council, Dhaka, Bangladesh.

REIS (1985) *Riverbank Erosion Study*, Jahangirnagar University, Bangladesh and University of Manitoba, Canada.

Shahid, S.M. (1994) *Data Collection and Analysis of Land Degradation*, Bangladesh Report, Bangkok, Rapa Publication; 1994/3.

SRDI (1997) Task Force Report. Soil Resources Development Institute, Dhaka, Bnaldesh.

UNDP (1989) Bangladesh Agriculture Sector Review.

Zaman, M.Q. and Babla, A.I. (1985) *Rural Bastee; A Socio-economic Background to the Squatter on the Jamuna Right Bank Embankment*, Dhaka, Bangladesh.

3.2.1 INTRODUCTION

Water is the most vital element among the natural resources, and is crucial for the survival of all living organisms. The environment, economic growth and development of Bangladesh are all highly influenced by water - its regional and seasonal availability, and the quality of surface and groundwater. Spatial and seasonal availability of surface and groundwater is highly responsive to the monsoon climate and physiography of the country. Availability also depends on upstream withdrawal for consumptive and non-consumptive uses. In terms of quality, the surface water of the country is unprotected from untreated industrial effluents and municipal wastewater, runoff pollution from chemical fertilizers and pesticides, and oil and lube spillage in the coastal area from the operation of sea and river ports. Water quality also depends on effluent types and discharge quantity from different type of industries, types of agrochemicals used in agriculture, and seasonal water flow and dilution capability by the river system.

Bangladesh is the lower riparian of three major river systems, the *Ganges-Padma*, the *Brahmaputra-Jamuna* and the *Meghna* (GBM), and constitutes about 8 per cent of the combined catchment area. Over 92 per cent of the annual runoff generated in the GBM catchment areas flows through Bangladesh (Coleman, 1969). The combined flow of the *Ganges* and *Brahmaputra* typically vary between less than 5000 m^3/s in the driest period (March-April) to 80,000-140,000 m^3/s in late August to early September (WARPO, 2000b).

The contribution of local rainfall to the annual surface runoff is about 25 per cent, with significant seasonal variation. Annual rainfall and evapotranspiration of the country show that there is a substantial excess of rainfall everywhere in the monsoon season. From the annual overall averages, dependable rainfall exceeds evapotranspiration by over 10 per cent in most parts of the country, except in the Northwest (NW) and Southwest (SW) regions. In the NW region, rainfall and evapotranspiration are almost equal, but in the SW the overall deficit is about 10 per cent. From November to May, evapotranspiration exceeds rainfall all over the country, except in the Northeast (NE) region (WARPO, 1999b).

The concerns over water quality relate not just to the water itself, but also to the danger of diffusion of toxic substances into other ecosystems. The aquatic environment for living organisms can be affected and bioaccumulation of harmful substances in the water-dependent food chain can occur. A variation of inland surface water quality is noticed due to seasonal variation of river flow, operation of industrial units and use of agrochemicals. Overall, inland surface water quality in the monsoon season is within tolerable limit with respect to the standard set by the Department of Environment (DoE). However, quality degrades in the dry season. The salinity intrusion in the Southwest region and pollution problems in industrial areas are significant. In particular, water quality around Dhaka is so poor that water from the surrounding rivers can no longer be considered as a source of water supply for human consumption.

The largest use of water is made for irrigation. Besides agriculture, some other uses are for domestic and municipal water supply, industry, fishery, forestry and navigation. In addition, water is of fundamental importance for ecology and the wider environment. Water stress occurs when the demand for water exceeds the amount available during a certain period or when poor quality restricts its use. This frequently occurs in areas with low rainfall and high population density or in areas where agricultural land or industrial activities are intense. Even where sufficient long-term freshwater resources do exist, seasonal or annual variations in the availability of freshwater may at times cause water quality degradation (EEA, 1999).

The Water Pollution and Scarcity section of the report deals with inland surface and groundwater quality, pollution problems, salinity attributed to low water flow and coastal water pollution. Other water-related environmental problems have been discussed in detail in other sections. For example, droughts and floods have been discussed under the Natural Disaster section. The Biodiversity section addresses the implications of shrinking dry season water area. Riverbank erosion and the consequences of gradual silt deposition in the floodplain are discussed under Land Degradation.

3.2.2 PRESSURES

For water resource analysis and planning, water demands have been categorized into consumptive and non-consumptive uses. Consumptive demands are those where water is lost from the resource pool and non-consumptive demands are those where used water is returned to the resource pool, and can be re-used (WARPO, 1999b). The consumptive use of water is increasing due to the growth of different economic sectors - agriculture in particular.

The increasing urbanization and industrialization of Bangladesh have negative implications for water quality. The pollution from industrial and urban waste effluents, and from agrochemicals in some water bodies and rivers have reached alarming levels. The long-term effects of this water contamination by organic and inorganic substances, many of them toxic, are incalculable. The marine and aquatic ecosystems are affected, and the chemicals that enter the food chain have public health implications.

Water quality in the coastal area of Bangladesh is degraded by the intrusion of saline water that has occurred due to lean flow in the dry season. This affects agriculture significantly, as well as other consumptive uses of the water.

A common phenomenon in the lower riparian countries is that of enough water in monsoon, but water scarcity during the dry season. It is also common in Bangladesh for areas that were once inundated facing water scarcity in the dry season. Dry season water availability depends on water use for irrigation, dry season rainfall and withdrawal or diversion of water upstream. It has implications for navigation, and the wetland ecosystem and its productivity.

Excess water in the monsoon causes floods and riverbank erosion, which result in loss of land and people being left homeless. This is discussed in detail in the Land Degradation and Natural Disaster sections. Although there is an abundance of water in the monsoon, often the water quality is compromised during floods, and this translates into a type of water scarcity when good potable water becomes difficult to obtain.

The inter-linkage of pressures, state, impacts and various policy responses to address water related environmental problems have been presented in Table 3.2.1. Detailed analyses of various policies and

Table 3.2.1 Inter-linkage of pressures, state, impacts, and various responses related to water

Pressures	State	Impacts	Policy Responses
Pollution • Industrial effluent • Agrochemical • Fecal Pollution • Ship breaking and lube oil discharge • Oil and lube spillage during normal refueling of ships at sea and river ports • Low water flow in the river system in dry season	• Decreasing inland water quality in dry season • Decreasing coastal water quality • Salinity intrusion in surface and groundwater • Soil salinity increase • No primary or secondary measurement is available on discharge quantity	• Pressure on urban water source • Fish fingerling mortality, migration and quality of fish • Degradation of fish habitat • Yield reduction (soil fertility loss) • Increase in risk from waterborne diseases • Affecting marine aquatic life	• Environmental Conservation Act and Regulation • Setup environmental quality standard • Industrial EIA and effluent treatment plants to reduce pollutants load • Polluters pay principle • National Water Policy: EIA for water development projects and increase surface water flow in dry season
Scarcity (dry season) • Upstream withdrawal for consumptive and non-consumptive use • Low rainfall • Gradual siltation in river bed and floodplain • Dry season irrigation • Flood	• Decline river water level and discharge • Low water flow • Shrinking dry season water area • Decline/fluctuation of groundwater • Less access to safe drinking water	• Decline in aquatic resources production • Navigation problem • Increase conflict among different users and sectors • Domestic uses • Increase pressure on groundwater • Quality of water decline	• National Water Policy: Dredging and water harvesting, regional cooperation, augmentation of dry season flow and use of surface water for irrigation
Abundance of Water (Monsoon season) • Geographical location and setting (92 per cent runoff flows through Bangladesh, which is 7 percent of the catchment area) • Monsoon Climate (78 per cent rainfall occurs in the monsoon)	• Increase flooding • Increase water related hazards • Increase river bank erosion • Increasing river bank shifting	• Crop yield reduction and damage • Disruption of livelihood system • Damage of homestead and towns • Population displacement	• National Water Policy: Structural and non-structural mitigation (early warning and flood proofing) • Planned development among different sectors need

Source: SoE Study Team

programs to address degradation of water quality and scarcity are presented in section 3.2.4.

3.2.2.1 Causes of Water Pollution

The major causes of degradation of inland water quality are related to land based activities, when adequate regulatory measures are not incorporated and the stakeholders do not show proper concern. The underlying driving forces for this are poverty, an unhealthy national economy, lack of institutional strength, and lack of awareness and education. Pollutants that enter the marine and coastal environment originate on land in the form of runoff from municipal, industrial and agricultural wastes, and from commercial seafaring activities.

Industrial effluent

In Bangladesh, industrial units are mostly located along the banks of the rivers. There are obvious reasons for this such as provision of transportation for incoming raw materials and outgoing finished products. Unfortunately as a consequence, industrial units drain effluents directly into the rivers without any consideration of the environmental degradation.

A view of industries, situated on the river banks

region, which comprises about 49 per cent of the total sector. About 33 per cent of the industries in the NC region are textiles, apparels and tanneries, of which Dhaka district accounts for almost half and Narayanganj about 32 per cent. About 65 per cent of the total chemicals, plastics and petroleum industries are also located in the NC region, and concentrated in and around Dhaka, Narayanganj and Gazipur districts (WARPO, 2000a). Region-wise numbers of industrial establishments and most polluting industries are shown in Table 3.2.2.

The organic pollutants are both biodegradable and non-biodegradable in nature. The biodegradable

Table 3.2.2. Region-wise Number of Industrial Establishments and Polluting Industries

Region	No. of Establishments	Textiles, apparels & tanneries	Paper, paper products & printing	Chemicals, plastics & petroleum	Non-metallic minerals manufactures
North West	4,403	545	113	181	360
North Central	12,133	4,093	707	1,242	733
North East	1,117	55	20	47	132
South East	2,518	346	68	83	549
South West	849	72	39	42	199
South Central	1,408	128	29	77	157
South East	2,506	475	102	231	229
Total	24,934	5,714	1,078	1,903	2,359

Source: WAROP, 2000a

The most problematic industries for the water sector are textiles, tanneries, pulp and paper mills, fertilizer, industrial chemical production and refineries. A complex mixture of hazardous chemicals, both organic and inorganic, is discharged into the water bodies from all these industries usually without treatment.

The highest numbers of industrial establishments in the country are located in the North Central (NC)

organic components degrade water quality during decomposition by depleting dissolved oxygen. The non-biodegradable organic components persist in the water system for a long time and pass into the food chain (Ahmed and Reazuddin, 2000). Inorganic pollutants are mostly metallic salts, and basic and acidic compounds. These inorganic components undergo different chemical and biochemical interactions in the river system, and deteriorate water quality.

Agrochemical

The main suspected sources of agricultural runoff pollution are from the use of fertilizers and agrochemicals, including herbicides and pesticides. Urea, Triple Super Phosphate (TSP), Muriate of Potash (MP) and Gypsum are the major chemical fertilizers used in Bangladesh. The total amount of fertilizers used annually is about 2 million tons. With the increase of irrigated areas and cultivation of HYV rice, there was an increase of about 20 per cent fertilizer use in 1990. But the present growth in use has decreased and fluctuates from plus minus 5 to 10 per cent. In 1995, the use of nitrogenous fertilizer accounted for about 88 per cent of the total fertilizer use, which was about 67 per cent in 1991. The share of the market held by domestic production of Urea, TSP and Gypsum is currently about 90 per cent (BBS, 1979, 1985, 1990, 1994, 1998).

Pesticide use was introduced in Bangladesh in 1957. Since 1981, the area covered by plant protection measures has actually decreased, though the trends have been erratic. Insecticide is commonly used for pest control, which accounts for about 90 per cent of the total consumed pesticide (BBS, 1985, 1998). The trends of irrigated land, and the use of chemical fertilizers and pesticides from 1991 to 1995 are presented in Figure 3.1.1 in the Land Degradation section.

Fecal Pollution

Bangladesh has the highest rural population densities in the world, and with an exception in some areas, the overall density is very high. Most of the rural areas have densities around 1,000 people per km², and over one third of the *thanas* exceed this. The main problem poses in respect to water is the lack of sanitation facilities in the rural areas and inadequate facilities for urban wastewater treatment. There is one sewage treatment plant in the whole country, serving only a part of Dhaka. A major program for provision of sewerage is needed to arrest the increasing fecal pollution of open watercourses around all urban areas in Bangladesh, particularly Dhaka. Outside the urban areas, there is a problem with designing adequately sealed latrine systems at the household level, which can cope with the annual flooding and prevent fecal pollution of the water supply. Poor management of wellhead areas may be the most significant source of fecal contamination rather than direct aquifer pollution.

Oil and Lube Spillage

Chittagong and Mongla are the two seaports of the country, and on an average deal with 1500 to 1600 vessels and 12,000 to 13,000 cargos annually (BBS, 1998). These ports, however, do not have facilities to receive and treat bilge and ballast water, and thus ships throw wastewater into the territorial waters of Bangladesh. Oil and lube spillage also happens during refueling of vessels and cargo handling. In addition, there are innumerable mechanized trawlers and boats engaged in fishing in the Bay of Bengal. The operators of these vessels dump waste, including burnt oil, into the water, because of their ignorance about its adverse effect on environment.

As the seaports and the harbors of Bangladesh are located near shallow water, large oil tankers carrying crude and refined oil cannot enter them. Therefore, oil spills also take place in outer anchorage during the transfer of crude and refined oil from large oil tankers to small tankers. There have already been several environmental disasters due to heavy spillage from oil tankers in outer anchorage and along coastal areas. In late 1989, a Greek-owned Cypriot flagship charted to bring crude oil for the Bangladesh Petroleum Corporation caused about 3,000 tons of oil slicks along the Chittagong Cox's Bazar coast. The vessel developed a hole through which crude oil oozed out, but authorities only detected it as the vessel rose higher as it was unloaded at outer anchorage. A huge oil slick was also detected around the Khulna coast in 1992, which was dumped from a foreign ship. But the authorities concerned failed to identify the vessel responsible for this (Majumder, 1999).

Lube oil and heavy metals enter the coastal area water from the ship-breaking industries in Chittagong, and several accidents have occurred. However, there is no assessment available on the amount of lube oil discharged from ship-breaking industries. Concern over this pollution in the coastal area is emerging, and actions to prevent it are in the initial stage. Enforcement of ECA and ECR, with institutional strengthening, is essential to address this problem.

Low Flow in Dry season

A certain level of stream flow is required to maintain navigability, the wetland habitat and ecosystem, and equilibrium between freshwater and saline water mixing zones. Generally, reduction of water flow causes saline water intrusion into the river system. Saline water intrusion is aggravated in the coastal area

of the country in dry season, when water flow from the river system becomes lean. Over the past two decades, the lowest water level data of the major rivers showed a declining tendency in the dry season (BBS, 1985, 1992, 1998). However, scientific research is required to establish whether decreasing water level has a direct linkage or not with salinity increase in the coastal area.

3.2.2.2 Causes of Scarcity

Generally, water scarcity is a dry season phenomenon when the availability becomes less than the demand or the quality of the water restricts its use. Dry season water resources are comprised of the runoff and trans-boundary river inflow, together with water contained in surface water bodies and groundwater. Scarcity is also dependent on the amount of soil moisture available at the beginning of the season. Trans-boundary inflow in the dry season has decreased due to upstream development, and withdrawal of water for irrigation and other purposes. Groundwater is the major source of irrigation in Bangladesh, and there has been a tremendous increase in suction mode irrigation. The following section presents a brief description of the causes of water scarcity in dry season.

Upstream Withdrawal and Diversion of Flow

As a lower riparian country, Bangladesh has 57 trans-boundary rivers, of which 54 are shared with India and 3 with Myanmar. The upper riparian countries have adopted innumerable development schemes in the upstream regions of these rivers. Apart from big barrages and other river based constructions near the border of the country, there is construction of spurs and weirs going on in other minor rivers such as *Dhalai* and *Kachamara*, a blockage on the *Sonai* river, barrage over the *Khowai* and *Gumati*, and many other structures on a number of rivers (Nazem and Kabir 1986). A significant amount of dry season stream flow is withdrawn and diverted upstream both inside the country and outside by neighboring countries, for irrigation and navigation. Withdrawal of water inside the country is done mainly for irrigation.

Dry Season Rainfall

The National Water Management Plan Project has considered the dry season to be from November to May, when rainfall is scanty, irregular and erratic. There is hardly any rainfall, except for the pre-monsoon months of April and May. Over this seven-month period, only 22 per cent of rainfall occurs, and evapotranspiration is four times higher than the rainfall (WARPO, 1999b). The maximum deficit of water is in the southwest and northwest regions of the country. Dry season rainfall plays a very important role for irrigating HYV *Boro* and reduces pressure on groundwater extraction for irrigation.

Gradual Siltation in River Bed and Floodplain

The three major rivers, the *Ganges*, the *Brahmaputra* and the *Meghna*, with their innumerable tributaries and distributaries used to carry about 2.0 to 2.4 billion tons of sediment every year into the country (Colemen, 1969, Milliman and Meade, 1983). But the recent estimate is somewhere between 1.2 to 2.0 billion tons. This indicates that there is a decrease in sediment load in the river system. Only about 5 per cent of the sediments are deposited in the riverbed and floodplain, and the rest are discharged into the Bay of Bengal (Hossain 1992).

Besides the regional geography, irrational use of forestland and other natural resources in areas up and downstream of the rivers for human activities lead to an increased sediment load in the river system (Islam, 1986). In the dry season, the in-stream sedimentation rate is increased due to an interruption of natural water flow. This creates strips of raised land, called *"Char"*, inside the river channels, which reduce the navigability.

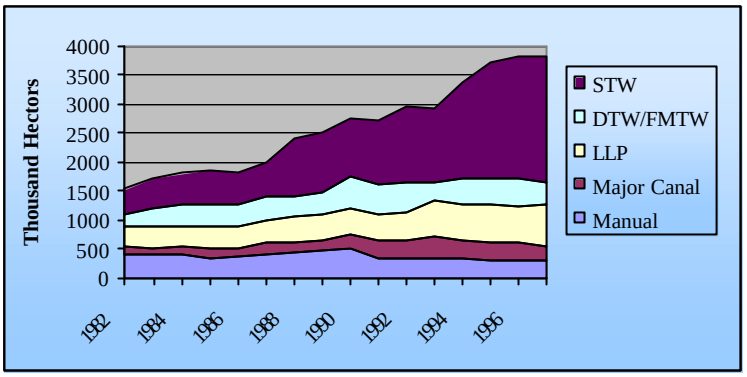
Deposition of sandy materials on agricultural land is frequent in the lower regions of the piedmont areas of north Netrokona, and the valleys of Sylhet and Chittagong Hill tracts. It happens because of the deforestation of the hills in the upper catchment areas. During the monsoon season, heavy rainfalls occurs in the upper hill areas and causes flash floods in the lower plains. With the runoff the water carries sandy sediments that spread over the floodplain. This shrinks the water holding capacity of the low-lying areas. For example, siltation in the *Kaptai* Reservoir has increased from 1 mm to 1.2 mm per year due to deforestation and improper agricultural activities in surrounding hilly areas over the last decade (Hossain, 2000a). The impacts of gradual siltation of the land and the reduction of soil fertility are discussed in the Land Degradation chapter.

Withdrawal of Wetland Water

Withdrawal of water from wetland *haor*, *baor* and *beel* for irrigating agricultural lands, as well as for

fishing, is a very common practice. Different agencies at different places all over the country have noticed the impacts of this ill-judged practice. The noteworthy impacts of such water use are the declining trend in production of aquatic species, and destruction of habitat for other wetland dependent species. The government of Bangladesh, among others, has initiated a new approach of "Community-Based Management of Aquatic Ecosystems" on a pilot scale to restore aquatic habitats and improve the quality of life of the local community.

Figure 3.2.1 Irrigated area in dry season by different technology



Source: WARPO, 1999b, Topic Paper 7

Dry Season Irrigation

Agriculture consumes the highest amount of water among the consumptive uses, in particular irrigating HYV crops. Over the last three decades, much effort has been put into intensification of agriculture by promoting dry season cropping through irrigation. Future demands of water for this will depend on the government policy for irrigated crop development.

A view of wetlands in dry season

Groundwater is an alternative source of water in dry season. A recent study shows the trends in groundwater use for irrigation and annual level of natural recharge. It shows that the groundwater aquifer is recharged annually through rainfall and flooding, and replenishes every year; except underneath Dhaka city, where an imbalance between recharge and groundwater extraction have been established (WARPO, 1999b). However, it is important to note that due to excess withdrawal of groundwater, water contamination such as arsenic pollution is on the rise. Thus, further use of groundwater does need re-evaluation.

The overall present trend of irrigated areas shows a steady rise (Figure 3.2.1), although a leveling off may be found in some areas. The trend may indicate that suction mode irrigation development has reached its limit in these areas, other non-resource factors may also influence the figures. These include land availability, the conflict between overlapping crops (e.g., transplanted *Aman* and wheat), the cost of growing *Boro* on permeable soils, and social and economic factors such as land ownership.

Climate variability and change is also an emerging issue that requires further assessment with respect to water resource management. As part of its program on climate change, the Government of Bangladesh has done an initial assessment incorporating the climate change scenario. Research and development on low water demanding and drought-tolerant crop varieties are also necessary.

Floods

Monsoon is characterized by excessive rainfall and surface runoff, which is mostly generated outside the geographical boundary of Bangladesh. About 78 per cent of the total rainfall occurs in the five months starting from June to October (WARPO, 1999b). The combined effect of surface runoff and monsoon rainfall makes the country vulnerable to flooding, which causes other water-related problems. Of major concern during floods is access to drinking water and its purity. The higher total and fecal coliform levels in the surface water at such times leads to a high incidence of diarrheal diseases, particularly surrounding the urban areas. Study results show that the surface water quality of Dhaka City during the 1998 flood was highly polluted and crossed the safe threshold limit set by the Department of Environment (Yusuf, 1998).

3.2.3 STATE AND IMPACTS

There are several government departments in Bangladesh dealing with water pollution and scarcity problems. Among them, the Department of Environment (DoE) deals with pollution issues. The Ministry of Water Resources, Ministry of Communication and Ministry of Agriculture, through its different branches, deals with scarcity.

DoE has been collecting data on surface water quality since 1980, at 11 points spread amongst five rivers of the country, i.e., *Buriganga*, *Sitalakhya*, *Balu*, the *Jamuna*, and the *Meghna*. Most of these points are located either towards the borders of the country or adjacent to known sources of pollution problems. A further 36 sites were added in 1991, of which only 14 sites are located in Dhaka and Chittagong Divisions. The relevant divisional offices of the DoE are collecting data on the remaining 22 points. Some sites are designated as Global Environmental Monitoring System (GEMS) points, the results of which are forwarded to Nairobi, Kenya, as part of an international commitment of the Government of Bangladesh. At present, DoE is monitoring water quality data at 69 stations, the details of which are presented in Table 3.2.3.

Various key parameters and indicators of water quality are monitored by the DoE. These include physiochemical characteristics of water, like the pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), suspended solids (SS), total coliforms, heavy metals, electrical conductivity (EC), chloride, turbidity, total alkalinity and temperature.

The Bangladesh Water Development Board (BWDB) collects data on suspended sediments and surface water salinity. Data on surface water and groundwater salinity of the coastal area of the country are collected by the Soil Resources Development Institute (SRDI), and are available from 1990 to 1997.

The main source of data for groundwater quality is the Department of Public Health Engineering (DPHE), particularly for domestic water supply. Since the late 1980's, DPHE has undertaken routine monitoring of basic water quality parameters at production wells in different district centers. In Dhaka and Chittagong, Water Supply and Sewerage Authority (WASA) periodically monitors production wells. Since 1965, the monitoring programs of the Bangladesh Water Development Board include 19 parameters for 115 tubewells. Sampling work was also carried out under the Bangladesh Agricultural Development Corporation (BADC) Deep Tubewell Programs, covering the period 1977 to 1992, followed by the National Minor Irrigation Development Project (NMIDP). The recently completed, Groundwater Studies for Arsenic Contamination in Bangladesh, summarized the groundwater situation in the country, and in addition to arsenic levels, gives a wider analysis.

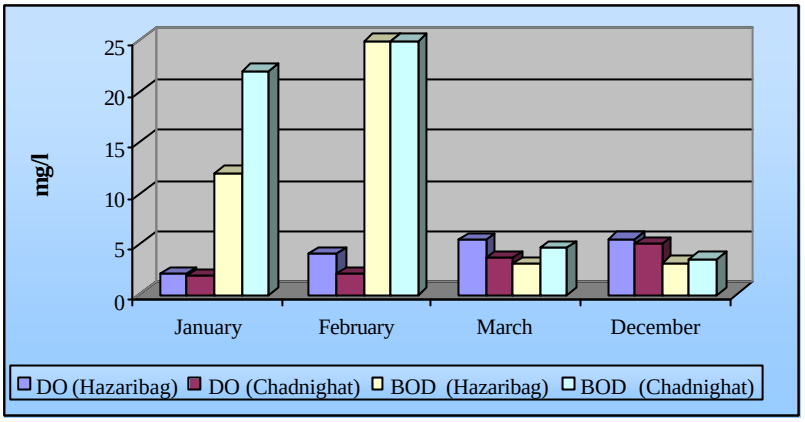
Table 3.2.3 Designated Stations for Water Quality Monitoring by DoE

Division	Name of the River	Number of Stations
Dhaka	Balu River	1
	The Brahmaputra River	5
	Buriganga	15
	Jamuna	2
	Meghna	2
	Sitalakhya	3
	Turag	1
	Dolasoria	1
	Kaligonga	1
	.....	1
Chittagong	Dakatia River	1
	Halda	4
	Karnaphuli	1
	Kushiara River	1
	The Meghna River	1
	Surma River	4
	Kaptai Lake	1
Rajshahi	The Jamuna River	1
	Isamoti River	1
	Korotoya River	2
	The Padma	2
	Tangs River	1
	Tista River	3
Khulna	Bagherhat River	1
	Balesher River	1
	Bhoirab River	7
	Beel Dakatia	1
	Doratana River	1
	Gabkhan River	1
	Kakshialy River	2
	Kirtankhola River	1
	Kumar River	2
	Madhumati River	1
	The Padma	2
	Pashur River	1
	Rupsha	3
	Shugandha River	1
Total		69

Source: Rahman, October, 2000

Different industrial units, particularly pulp and paper mills, and fertilizer factories monitor surface water quality in the dry season, in order to maintain industrial production. In addition, a few other projects have collected data on inland and coastal water quality to cover their study objectives. Data on coastal water pollution and its sources are very scanty and unpublished. The Ministry of Defense and the Marine Science Institute of Chittagong University have some unpublished data on coastal and marine water quality of the country.

Figure 3.2.2 Water Quality of Buriganga, 1998



Source: Department of Environment, 2000

3.2.3.1 State and Impacts of Water Pollution

Longitudinal analysis of surface water quality data is difficult due to the absence of consistent data at the same monitoring points. In addition, the seasonality of flow in the watercourses from the main rivers constitutes a significant constraint to their ability to dilute and disperse effluent discharged into them. This becomes complicated further by the fact that some of the discharges are themselves seasonal in nature. Issues of concern regarding water quality data on the depths from where the samples were taken, and the state of the tide at that time in those areas. However, there is little debate that there are "hot spots" of water pollution due to industrial effluents around the major cities, i.e., Dhaka, Chittagong, Khulna and Bogra.

Inland Surface Water Pollution

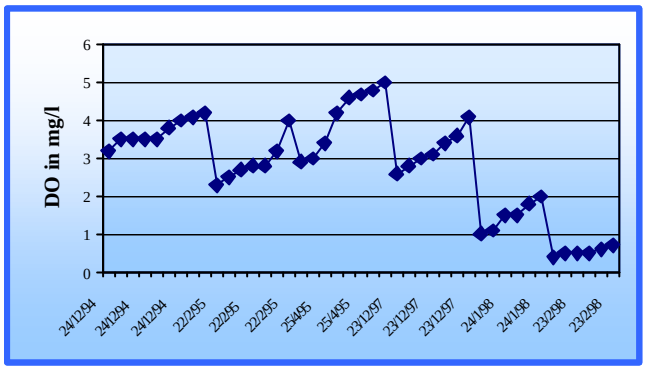
The overall inland surface water quality in the monsoon season is within tolerable limits, with a few exceptions, including the rivers *Buriganga*, *Balu*, *Shitalakhya*, *Karnaphuli*, and *Rupsha*. However, concerns over surface water quality are gradually emerging due to the dispersed locations of polluting industries, and the adverse effect on surrounding land and aquatic ecosystems, as well as subsequent impacts on the livelihood system of the local community. The extreme examples of this type of effect are near Dhaka at Konabari and Savar, where industrial effluents are discharged into nearby land and water bodies without any treatment.

Among the polluted areas, the worst problems are in the River *Buriganga* situated to the south of Dhaka, where the most significant source of pollution appears to be from tanneries in the Hazaribagh area. In the dry season, the dissolved oxygen level becomes very low or non-existent and the river becomes toxic (WARPO, 1999a). Water quality data at two stations of the river *Buriganga* in 1998, Hazaribag and Chadnighat, showed that DO and BOD exceeded the tolerable limits in the months of January, February, March and December, with the worst situation prevailing in the months of January and February (Figure 3.2.2). The seasonal variation of water quality in the *Buriganga* is linked with seasonal variation of water flow and the operation of tanneries. The recent construction of the nearby flood protection embankment, whilst concentrating the effluent near the works, may have the possible advantage of restricting the wider dispersion of this very heavy pollution.

The second most polluted river is the *Shitalakhya*, flowing from the east of Dhaka. The major polluters of the river are Ghorashal Urea Fertilizer Factory and an oil terminal situated on the bank of the river. Industrial units at Narayanganj and Demra are also sources of the pollution. Monitoring data of the DoE demonstrated that the concentration of dissolved oxygen in the river *Shitalakhya* beside the fertilizer factory varies between 2.1 to 2.9 mg/l during low tide (DOE, 1993). Monitoring data of the Surface Water Modelling Centre (SWMC) on the same river, showed a degrading trend for water quality in the dry season. The lowest level of DO was observed at the end of February 1998, when the concentration became less than one (Figure 3.2.3).

Water of the river *Balu* is badly contaminated by urban and industrial wastes from Tongi and the effluent flowing out through the *Begubari Khal*, most of which emanates from the Tejgaon industrial area in Dhaka. In the rivers *Balu* and *Turag*, water quality in the dry season becomes worse, with DO concentrations becoming almost zero (Saad, 2000).

Figure 3.2.3 Concentration of Dissolve Oxygen in the River *Shitalakhya* in different time of day and year



Source: SWMC

In terms of data from point sources on other rivers, there is a specific problem with the Jamuna Fertilizer Factory in the dry season. The low flow channel, which serves as both the source of processing water and recipient of wastewater, also increases the pollution level in the river. The discharge point has moved some 10 km away from the factory site, due to the complex erosion and accretion patterns.

One study was undertaken the year 2000 in Kaliakoir by the Bangladesh Centre for Advanced Studies (BCAS), for a project named "Management of Aquatic Ecosystem through Community Husbandry (MACH)". A number of textile and leather industries discharge their industrial effluents into a nearby small water body, *Mokesh Beel*. The study analyzed both water and sediments of the study area. The results showed that levels of COD, TSS and DO in the water exceeded standard limits. It also showed that the total chromium concentration in sediments and wastewaters near the discharge points of the local tannery and textile industries is very high. The concentrations of zinc, lead and cadmium were also found to be higher than the national standards (BCAS, 2000).

Groundwater Pollution

Groundwater has different uses, but the standard for its quality was set nationally. Groundwater was treated as the best source of safe drinking water, before arsenic contamination was reported. However, 54 per cent of hand pumped tubewells were found to have fecal contamination, due to poor wellhead design, faulty construction and management, but the aquifers themselves were not polluted (Hoque, 1998).

Arsenic

High levels of arsenic in groundwater can cause serious human health problems if imbibed for a long time (from 5 to 15 years); including skin ailments, damage to internal organs, skin and lung cancers, and eventual death. The recent major studies carried out on arsenic reveal that among 30,000 tubewells studied, 2,000 of them exceeded the national standard of 0.05 mg/l for drinking purposes (the WHO guideline is 0.01 mg/l).

The problem is acute in tubewells abstracting groundwater from 10 m to 100 m depths in the Southeast, South Central (the northern part only), and Southwest regions. To a lesser extent, the eastern part of the Northeast region, and the very southern fringe of the North Central and Northwest along the river Ganges are affected. The most seriously affected districts are Chandpur, and those around it. It was estimated that more than 20 million people drink water exceeding the national standard for arsenic levels.

The presence of arsenic is a naturally occurring phenomenon, but prolonged use of the water can be very harmful when the levels cross the standard limit. Contrary to earlier reports by the press, the available evidence strongly argues against the idea that arsenic contamination originates either from the use of synthetic chemicals, such as wood preservatives, or insecticides.

Arsenic contamination has considerably serious implications for groundwater abstraction in affected areas. This impinges on domestic water supply, since groundwater is the preferred source, because compared to surface water it is less likely to be fecally polluted. Already thousands of cases of arsenic poisoning have been recorded among local people, and some deaths have been reported. Clinical studies are being carried out by the Dhaka Community Hospital.

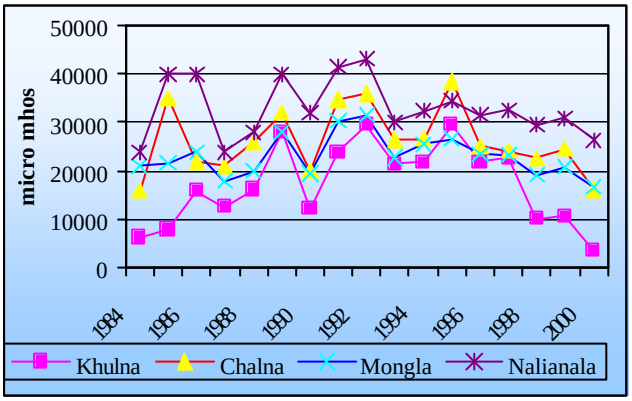
In agriculture, there are also serious implications from the possible transfer of arsenic into the food chain through crops that are under irrigation with arsenic-contaminated water, and then consumed by humans. There is little evidence of arsenic contamination in rice grains through irrigation with arsenic contaminated water. However, boiling rice in arsenic-affected water does lead to its contamination, which causes serious problems. The crops most likely to absorb arsenic from irrigation are leafy vegetables, and possibly coconuts, and melons. These crops pass arsenic into the food chain.

The effects of arsenic on pond-reared fishes are now under study. Livestock that drinks arsenic-contaminated water should also be under study, because humans consume these animals and their products. The infiltration of arsenic-affected water in the soil also needs to be studied, along with possibility of infiltration into shallow aquifers.

Source: WARPO, 2000b

Iron concentration in the groundwater in many parts of the country, particularly the central parts, is much higher than the WHO and national recommended limits, but there are no known human health implications. There are high natural occurrences of manganese (above the WHO guidelines for drinking water), particularly in the west, central and northern parts of the country. 30 per cent of wells have high manganese levels, and

Figure 3.2.4 Trend of Highest Salinity Concentration



Source: BBS and SWMC

this is harmful for human health (WARPO, 1999a). Concern also exists regarding the concentrations of manganese, boron, phosphorus phosphate, and nitrate from agrochemical residues in groundwater, some of which have already crossed the threshold limits, making it unfit for human consumption.

Coastal Water Pollution

The coastal morphology of the country is very dynamic, with a zone of freshwater and saline seawater interaction. There are two main problems existing in the coastal water bodies, namely, water pollution in the marine zone and salinity in the estuary. The magnitude of these problems depends on seasonal freshwater flow from river systems, pollution load through runoff from land based activities, operation of seaports and other sea-based activities (Hossain, 2000b).

Table 3.2.4 Dissolved metal concentrations in water along Chittagong and Cox's Bazar Coasts

Parameter	Mean (ppm)	Max (ppm)	Min (ppm)
Fe	0.43	1.02	0.00
Pb	0.35	0.60	0.04
Cd	0.06	0.10	0.03
Cu	0.04	0.08	0.01
Zn	0.08	0.18	0.02
Mn	0.04	0.41	0.00

Source: Chowdhury et. al., 1994

A preliminary assessment of water and sediment pollution load along the coasts of Chittagong and Cox's Bazar showed that the dissolved concentrations of metallic and non-metallic elements in water are higher towards the sea. Conversely, the metallic and non-metallic concentrations in the case of sediments are higher towards land. This is mostly due to land-based activities and untreated effluents from urban centers. The lead concentration has crossed the acceptable level (0.2 ppm) in most areas, except *Bakkhali*, lower *Kumira*, and upper and lower *Karnaphuli* (Chowdhury *et. al.*, 1994). Details of dissolved concentrations of metals in water samples are presented in Table 3.2.4.

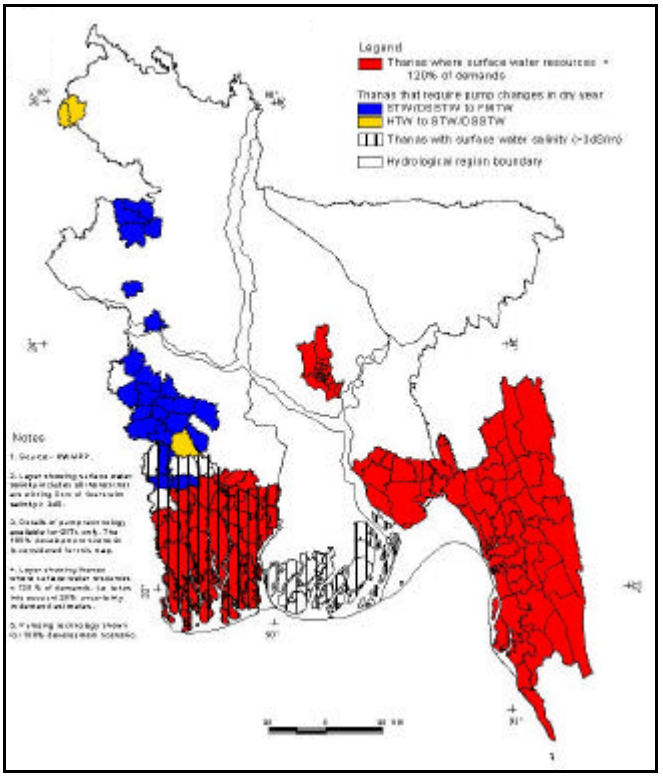
The DoE has conducted a survey on ship-breaking industries and seawater quality on the coasts. The survey results showed that about 50 ship-breaking industries are operating in the Chittagong region, discharging effluents that are polluting both the land and water environments. Concentration of DO varies from 5.6 to 5.8 mg/l and the BOD varies from 2.2 to 2.5 mg/l (DoE, 1997).

There is a seasonally moveable salinity interface in the estuaries, with the threshold limit for agriculture (2dS/m) moving inland in May in the southern part of Bhola and other southern islands. There are also salinity issues in the Southwest region, attributed to reduced dry season flows into the area from the *Ganges* system. During the 1990s dry season, salinity levels in the Khulna area rose, for which one of the likely causes was postulated to be the decrease in dry season surface flow from the *Ganges* (DHV, 1998). The highest salinity concentrations of four selected stations in the coastal rivers from 1984 to 2000 are presented in Figure 3.2.4. It shows an increasing trend up to 1996 in Nalianala, followed by Chalna, Mongla and Khulna. The situation has improved slightly after the signing of the "Ganges Water Sharing Treaty" in 1996.

The major groundwater salinity problem lies in the coastal areas of the country. This causes a constraint on its use, but there are some localized freshwater sources close to the coast. Upstream abstractions of groundwater reduce the ability of freshwater to hold back salinity intrusion, and this is reported to be a major concern in the Khulna area and other parts of the southern half of the Southwest region (WARPO,

1999a). Fresh groundwater in most coastal areas has to be abstracted from a depth of over 150 m, up to 450 m. This can be relatively expensive to develop and operate. Although this does restrict the use of the deep

Figure 3.2.5 Water Scarcity Zones



Sources: WARPO, 1999b

aquifer for irrigation, compared to shallow aquifers it has the benefit of being free from arsenic. There are also residual salinity problems in Comilla, Brahmanbaria and Chandpur caused by old deposits, from the time when the areas were under a marine ecosystem.

3.2.3.2 State and Impacts of Water Scarcity

The situation common in the country is that of an abundance of water in the monsoon and less water in the river system in the dry season. The impacts of scarcity of water in terms of quantity, as well as its quality, are immense, having effects on its demand for consumptive and non-consumptive use.

The significant environmental indicators for available inland water are lowering of water level and discharge in the major rivers. The fluctuation and lowering of groundwater levels are used for monitoring the situation. Dry season water flow, obviously depends on upstream water withdrawals, and therefore has cross-sectoral impacts. Lean water flow in the river systems has impacts on inland water navigation, aquatic resources, salt-water intrusion, pressure on groundwater and pollution dilution. Salinity and its impacts have been discussed earlier under Land Degradation, and the issue of aquatic resources and biodiversity has been discussed in the Biodiversity chapter.

Surface water scarcity is observed in the Sundarbans, Chittagong, Noakhali and Dhaka regions, where the ecological and environmental demands for surface water are higher than the supply. Figure 3.2.5 shows the spatial distribution of areas having water scarcity problems.

River Water Level

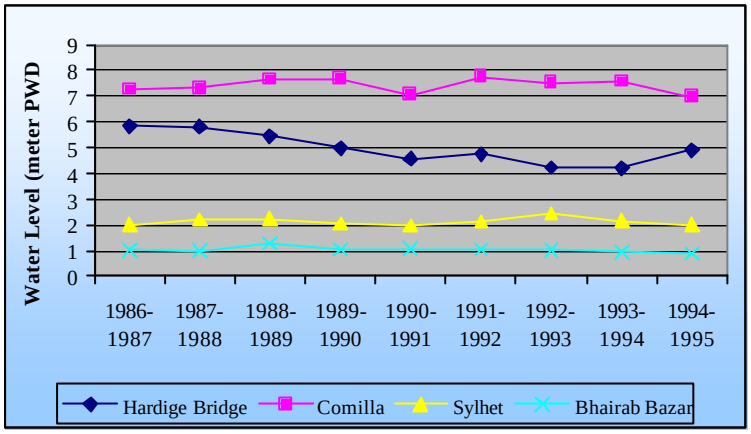
Over the last few decades the major river water levels in the dry season have shown a declining trend. As a result, there is practically no water flow in small tributaries and distributaries that do play an important role in agriculture, fisheries and biodiversity. The lean flow of the major rivers also play a critical role in saline water intrusion into the river system, navigation problems in the rivers, and puts pressure on groundwater for irrigation. All these ultimately results in yield reduction in coastal agriculture and industries, decline in the quality of coastal ecosystems, particularly the Sundarbans ecosystem, and decline in the groundwater table. Figure 3.2.6 presents the trend of lowest water levels of the *Ganges-Padma* and the *Meghna*, at Hardinge Bridge and Bhairabbazar, respectively.

One of the major impacts of the lowering in dry season river water flow is increasing surface water salinity in coastal areas and salt-water intrusion. Salinity plays a limiting role in crop agriculture and industrial production in the coastal areas of Bangladesh. The available literature on impacts of salinity on different crops suggests that the soil salinity reduces productivity of rice during its germination, vegetative (early) growth and reproductive stages (Bhumbla *et. al.,* 1968; Rai, 1977a; Rai, 1977b; Ayers and Westcot, 1976; Das *et. al*., 1971; BRRI, 1983; BARC, 1981-82 and BARC, 1982-83). The Land Degradation section deals in detail with salinity impact on crop agriculture in the coastal regions of Bangladesh.

Groundwater Level

WARPO recently analyzed the groundwater resources of the country under the “National Water

Figure 3.2.6 Trend of Lowest Water Level



Source: BBS, 1990, 1992, 1994, 1998

Management Plan Project". The study showed that the groundwater table of the country has been lowered over the last ten years (WARPO, 1999b). The analysis was conducted using data from the groundwater monitoring wells distributed all over the country. It was also found that natural inflow of groundwater to streams and other surface water bodies has reduced with increased use of pumping for irrigation.

The fluctuation of groundwater has been observed all over the country, and the highest levels of fluctuation are in the north central, northeast and southeast regions of the country.

The spatial distribution in a normal year of maximum depth to groundwater showed that in the northwestern part of the country the groundwater is at relatively less in depth, whereas the north central region has a deeper groundwater table. Spatial distribution of depth to groundwater in a normal year is presented in Figure 3.2.7.

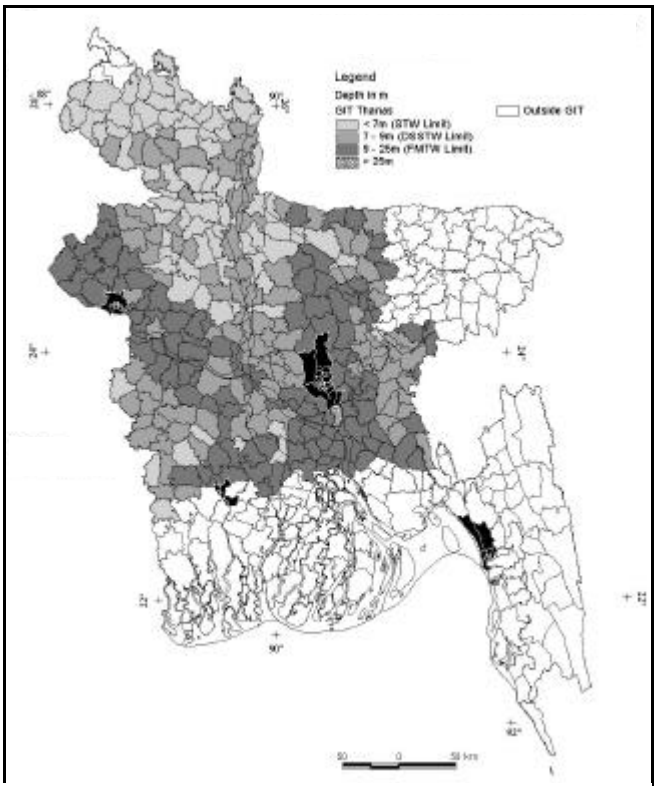
3.2.4 RESPONSES

The need for a human response to problems associated with water date back to the early history of civilization and development. Most of the responses were based upon water scarcity and abundance as constraints to development. Thus, many of the initial bureaucratic acts and rules pertaining to water in the region of Bangladesh were to meet sectoral demands and needs, for example, the Irrigation Act in 1876, and the Agricultural and Sanitary Improvement Act, 1929. The importance of comprehensive water development and management, with mostly supply-side management, was recognized after the flood havoc of 1954 and 1955, and its implementation was accelerated after the country got independence.

Water quality issues of the country (along with other environmental issues) were emphasized in the Bangladesh Environment Policy, 1992, and more detail was outlined in the Environment Conservation Act, 1995 and Environment Conservation Rules of 1997. The National Water Policy, 1999, also emphasized water pollution, and supply and demand side management. Nowadays, it is well recognized that it is not the acts, laws and rules addressing water pollution and management of water resources that are inadequate, but rather their enforcement. The following section will highlight major institutions involved in water management and its quality, along with their policies. It will also give an analysis of policy and program gaps, and the future course of actions that are required to attain the policy objectives and goals.

In 1983, the government initiated a National Water Plan (NWP) preparation exercise, which was completed in 1986 and was updated in 1991. After the

Figure 3.2.7 Maximum Depth to Groundwater



Sources: WARPO, 1999b

two consecutive devastating floods of 1987 and 1988, a five-year Flood Action Plan (FAP) project was launched, with an emphasis on flood mitigation measures. It was gradually recognized that the FAP studies should pay attention to integrated water resources management, and not just the problem associated with flood. In March 1998, the National Water Management Plan (NWMP) project was launched and its completion is expected by November 2001. The project will develop a water management plan up to the year 2025.

The massive general development effort of the government has led to the creation of a number of agencies responsible for water development in the country. A National Water Council has been formed, which consists of ministers and nominated members of parliament, headed by the Prime Minister. This committee is the highest decision-making authority for policy regarding water resources development in the country.

The Ministry of Water Resources is the principal government organization responsible for formulation of national plans for water resource development. Water Resources Planning Organization (WARPO) and with multidisciplinary professionals from other organizations, such as the Ministry of Agriculture, Inland Water Transport Authority (IWTA), DPHE, WASA under the Local Government and Rural Development (LGRD), Ministry of Environment and Forest (MoEF), and Ministry of Fisheries and Livestock (MoFL).

The Bangladesh Water Development Board (BWDB) was established in 1972, from the division of the former East Pakistan Water and Power Development Authority (EPWAPDA) into the two separate Water Development and Power Development Boards. It is under the Ministry of Water Resources, and is the organization responsible for implementation; operation and maintenance of water related projects. This includes surface water irrigation, drainage, flood control, erosion control, town protection and river training throughout the country.

3.2.4.1 Institutions

Department of Environment (DoE)

The primary institution for environmental management is the Department of Environment (DoE), under the Ministry of Environment and Forest (MoEF). The DoE is the authority with the mandate to regulate and enforce environmental management, and the setting and enforcement of environmental regulations, including the pollution control of water resources.

Its key duties related to the water pollution include:

- Pollution control, including monitoring effluent sources and ensuring mitigation of environmental pollution;
- Setting Water Quality Standards (WQS) for particular uses of water and for discharge to water bodies;
- Defining Environmental Impact Assessment (EIA) procedures and issuing environmental clearance permits - the latter being legal requirements before proposed projects can proceed to implementation;
- Providing advice or taking direct action to prevent degradation of the environment;
- Declaring Environmentally Critical Areas (ECAs) where the ecosystem has been degraded to a critical state. ECA status confers protection on land and water resources through a series of environmental regulations.

Water Resources Planning Organization (WARPO)

Under the National Water Policy (NWPo), the National Water Resources Council (NWRC) forms the apex coordinating body for water resources management. WARPO is the mandated planning agency for water resources management and acts as the Secretariat of the Executive Committee of NWRC (ECNWRC). As the Secretariat of ECNWRC, WARPO has the responsibility to advise on policy, planning and regulatory matters concerning water resources, and related land and environmental management. It is also emphasized in the NWPo that the activity of WARPO should be complementary to the role of DoE, and active cooperation between the two organizations needs to be strengthened. The involvement of WARPO in pre-screening EIAs for water sector projects, in advance of submission to DoE for final clearance, would relieve part of the burden on DoE. In addition to its contribution in such clearing-house activities, the WARPO Environmental Section is being prepared to play an active role in raising environmental standards as a whole in the water sector. To this end, WARPO is expected to progressively undertake the following functions:

- Participation in the development of the NWMP, and subsequent updates to ensure fulfillment of NWPo environmental objectives;
- In collaboration with DoE and other line agencies, develop environmental standards and guidelines relevant to the water sector, in conformity with the NWPo, and the various laws and regulations;
- Monitoring the efficacy of water sector standards and guidelines in achieving the aims and objectives of the NWPo and NWMP, and as necessary recommending improvements;
- Raising environmental awareness of water-related issues through relevant agencies to wider civil society;
- Advice on environmental impacts of the portfolio of projects included in other government departments with an interest in environmental management of water resources, such as the Department of Fisheries (DoF), under the Ministry of Fisheries and Livestock (MoFL), and the Forest Department (FD). The DoF has field-based staff down to *thana* level, and with the Ministry of Lands (MoL) is at present responsible for the management of public water bodies. However, this is changing, as shown by the recent (August 2000) transfer of responsibility for water bodies larger than 20 acres from MoL to MoFL for a ten-year (renewable) period.

There are also many important non-government organizations (NGOs) in Bangladesh with environmental interests. These include: the International Union for the Conservation of Nature (IUCN), National EIA Association, International Centre for Living Aquatic Resources Management (ICLARM), Bangladesh Centre for Advanced Studies (BCAS), Surface Water Modelling Centre (SWMC), Environment and GIS Support for Water Sector Planning Project (EGIS), Local Government Engineering Department (LGED) and the Bangladesh Environmental Lawyers Association (BELA). ICLARM has specific wetland management programs for the country. BCAS has provided assistance to the MoEF and prepared National Environment Management Action Plan (NEMAP). Apart from being a significant lobbying body, BELA has also provided assistance with drafting environmental legislation, and is beginning to place public-interest litigation on environmental cases before court. The Coalition of Environmental NGOs (CEN) is the lobbying organization for national NGOs with regard to environmental matters. In addition, there are single-issue NGOs, some of whom have area-based operations, and specific environmental interests which relate to the water sector. As an example of such an organization is the Coastal Area Resource Development and Management Association (CARDMA).

3.2.4.2 Major Policy Responses

National Environment Policy, 1992

The National Environment Policy was drawn up in 1992 based on the IUCN concept of sustainable development, which was an outcome of the National Conservation Strategy.

The objectives of the NEP are to:

i) Maintain ecological balance and overall development through protection and improvement of the environment;

ii) Protect the country against natural disasters;

iii) Identify and regulate activities which pollute and degrade the environment;

iv) Ensure development that is environmentally sound for all sectors;

v) Ensure sustainable, long-term, and environmentally sound use of all national resources;

vi) Actively remain associated with all international environmental initiatives to the maximum possible extent.

The 1995 NEMAP aimed to institutionalize both the Policy and the NCS into a strategy that could be implemented. NEMAP was based on a national consultative process to identify the main environmental issues in the country, including those that relate to water pollution and scarcity.

National Water Policy, 1999

With over 50 clauses of relevance to the environment, the 1999 National Water Policy (NWPo,) forms a comprehensive framework for ensuring activities in the water resources sector are fully environment friendly. Its many environmental concerns and specific demands recognize that most of the country's environmental resources are linked to water. Compliance with the Policy will ensure that the development and management of the nation's water resources include protection,

restoration, preservation of natural habitats and their dependent bio-diversity, and water quality - with specific provisions for wetlands, mangrove and other forests, and endangered species. The Policy also prescribes water resource management practices that avoid, or at least minimize, environmental degradation. Specific provisions include:

- Protection, restoration and enhancement of the water resources;
- Protection of water quality, including strengthening of the regulations concerning agro-chemicals and industrial effluent monitoring;
- Facilitation of potable water and sanitation provision;
- Provisions for fish and fisheries;
- Participation of local communities is a requirement for all water sector development as a subject to an environmental assessment procedure and for the planning and management process.

In addition, the Government of Bangladesh has signed several international conventions that have implications for environmental aspects of water resources planning. The major conventions are: Agenda 21, the 1992 Rio Convention on Climate Change and Biological Diversity, the 1971 Ramsar Convention on Wetlands, the 1973 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the 1954 International Convention for Prevention of Pollution of the Sea by Oil. Under the last, permitted discharge amounts and locations from ships are specified. Bangladesh has also ratified the Marine Pollution Conventions (MARPOL). These conventions regulate handling of domestic and (bilge) oil waste from ships, and receptor facilities in harbors, as well as domestic and waste oil handling from oil platforms.

3.2.4.3 Legal and Regulatory Framework

As a response to the National Environment Policy, 1992, the following critical pieces of environmental legislation have been set as the framework for environmental management of the country:

i) The 1995 Environmental Conservation Act

ii) The Environmental Conservation Rules of 1997

iii) The 1997 EIA Guidelines for Industries

iv) The 1999 Environmental Court Act

The Environmental Conservation Act and Rules

The 1995 law is an enabling act, which gives the MoEF the power to draw up rules and guidelines for managing the environment. The law also designates the DoE as the responsible body for enforcing the EIA procedures outlined in the 1997 Rules, along with the legal procedures to be followed for implementing the EIA process. The rules also designate four classes of possible interventions by degree of expected environmental impact. The Environmental Conservation Rules also contain national environmental standards, including those for water quality standards for different sectors and purposes.

The EIA Guidelines for Industry

Despite its title, the EIA Guidelines for Industries covers significant water sector interventions, including flood control embankments, polders, dykes, water supply and sewage treatment, as well as roads and bridges. All these water sector interventions fall under the 'Red' category, with the exception of bridges less than 100 m long, and feeder and local roads. This requires the most stringent EIA process to be followed for proposed project construction, re-construction and extension.

The responsibility for following the environmental assessment procedure lies with the project proponent or developer. The procedures are different, depending upon the categorization of the proposed intervention. The two most stringent classes, Orange/Amber B and Red, are required to have an Initial Environmental Examination (IEE), with an Environmental Management Plan (EMP). The red classification requires an additional full EIA to be undertaken. Once the DoE approves these documents, then a Site Clearance Certificate is issued - provided the developer has obtained a 'No Objection Certificate' from the local authority.

Environmental Quality Standards

The National Environmental Quality Standards are given in the Environmental Conservation Rules of 1997. These set a range of water quality criteria and limits depending upon the intended uses, including use for human drinking water, livestock drinking, fisheries, recreation, irrigated agriculture and industry. Discharge standards are also specified by sources, including public sewage outfalls, irrigation

water and specific types of industrial discharges by size. The overriding problem of environmental standards in Bangladesh is the difficulty in enforcing them.

Moreover, the regulations are essentially 'end-of-pipe' standards, or just abstractions. Although there is an Ambient Water Standard, it covers none of the many chemical pollutants known to be discharged. There is no effective regulation that takes into account the ability of rivers to dilute and disperse effluent, especially in times of low flow, and under complex cumulative discharge patterns. These cumulative impacts are crucially important for the natural aquatic environment.

EIA Guidelines for the Water Resources Sector

The environmental component of the Flood Action Plan, FAP 16, drew up a set of EIA Guidelines, which were approved by the MoEF and DoE for use in the water resources sector; and they were adopted by FPCO and WARPO in 1992.

In addition to the water resources EIA Guidelines, FAP 16 drafted a manual in 1995 for carrying out EIA. The manual was intended to assist people not familiar with EIA work, and to give more detail on the use of the Guidelines for a wide range of water sector projects. Under SEMP, the DoE has recently started drafting 18 sets of sectoral EIA Guidelines. WARPO and DoE are at present collaborating on new guidelines for the Water Resources Sector, which in time ought to replace the water resource sections of the Industry Guidelines.

3.2.5 GAPS AND FUTURE CONCERNS

Notwithstanding the large number of rules and regulations to protect water from industrial effluents and other pollution, and the policies for enabling the environment through dry season augmentation of water, there is a lack of institutional capability to enforce them, and there are few action programs. There is also a lack of skills and expertise for taking appropriate action

Table 3.2.5 Policy, legal and regulatory framework, and actions programs to address the water pollution and scarcity

Pressures	Policy, Legal and Regulatory Framework	Program Undertaken	Probable Options to Address the Problem
Industrial Effluent	Industrial Policy, Environmental Conservation Act and Regulation, Guidelines for Industrial EIA	There is very limited action program. Need institutional strengthening, and enforcement of laws and regulations	Installation of Treatment Plant, Land Zoning, Enforcement of ECA and ECR
Agrochemical	Agricultural Policy. Government has regulatory body, with some departmental rules to oversee import of agrochemicals and their use. However, legal and regulatory framework is not present	Need wider dissemination of knowledge regarding balanced use of agrochemicals. Need legal and regulatory framework for banning import of hazardous agrochemicals	Awareness Campaign, Proper use of Agrochemicals and Introduction of IPNS
Fecal Pollution	Safe water supply, and sanitation policy	Both government and non-government organizations are working in water supply and sanitation. Municipal wastewater treatment needs more attention as very limited measures have been done	Safe Sanitation System and awareness raising
Ship-breaking and lube oil discharge at sea	Bangladesh signed the UN Convention on the Law of the Sea in 1982. Environmental Conservation Act and Regulation	There is very limited action program. Need institutional strengthening, and enforcement of laws and regulations.	Enforcement of ECA and ECR, West reception and treatment facilities at port
Low water flow in the river system in dry season	National Water Policy. Ganges Water Treaty	Augmentation of dry season water flow, consumptive use of surface and groundwater for irrigation. Ganges Barrage	Strengthening of regional cooperation, implementation of Ganges Barrage project
Upstream withdrawal for consumptive and non-consumptive use	Ganges Water Treaty. National Water Policy: Dredging and water harvesting, regional cooperation, augmentation of dry season flow, and use of surface water for irrigation	Regional cooperation and need institutional strengthening and financial support. Awareness-raising for consumptive use of surface and groundwater for irrigation	Strengthening of regional cooperation

Source: SoE Study Team

during project design and implementation, to ensure that environmental concerns should be properly addressed. The most important issue is the apparent overlap in the mandates of the Ministry of Environment and Forest (MoEF), WARPO and NWRC in developing policies regarding water resources development and management. However, over the last decade progress has been made, particularly in identifying environmental issues and potential solutions. An analysis is presented in Table 3.2.5 of policy, legal, and regulatory frameworks, and action programs to address water pollution problems.

Future concerns prevail regarding the implementation of national policies, due to lack of institutional capability and awareness to properly address the policy objectives and goals. Earlier analysis of climate change scenarios show that water scarcity in the dry season would be aggravated, and low water flow in the river system would allow further saline water intrusion into it. Therefore, climate change and its impact on water pollution and scarcity need further integrated analysis. An analysis is presented in Table 3.2.6 on possible future concerns and implications of various national polices on water-related environmental issues and required actions.

Table 3.2.6 Future Concerns regarding other National Polices and Water-related Environmental Issues

National Policy and Key Water-related Environmental Issues	Future Concerns/Implication	Need to Address the Issues
Agriculture (1999): Increased food crop production for food security; environmentally-friendly, sustainable agriculture; strengthening of agro-forestry; research, e.g. on fish and rice; introduction of improved HYVs	Possible land use competition and increased water pollution due to unbalanced use of agrochemicals, though the policy document emphasizes more balanced use of agrochemicals	Strengthening of existing dissemination activities about balanced use of agrochemicals. This should be based on agro-ecological units and soil requirement
Energy (1995): Expansion of generating capacity	Chemical and heat pollution of water.	Enforcement of environmental laws and regulations
Fisheries and Livestock (1998): Conservation of fish habitats, including fish sanctuaries; integrated fish/shrimp/rice production; banning agro-chemicals; promotion of culture fisheries; banning complete dewatering of water bodies; conservation of fish and other biodiversity; sustainable coastal fish/shrimp production; fisheries committees at all levels	Possible land use competition and population pressures to meet demand, particularly between HYV *Boro* and overexploitation of aquatic resources	Harmonization of Agriculture, Fisheries and Livestock Polices. Awareness-raising at community level and develop appropriate land use and cropping pattern
Forestry (1994): Wildlife protection and biodiversity conservation; afforestation; prevention of adverse impacts on mangroves and other ecosystems; integrating of trees and traditional land uses, expansion of forest area	Land use competition, and raising conflict among the sectors.	Harmonization and coordination among different ministries and departments. Awareness-raising among the different stakeholders
Industry (1999): Raising industrial share of GDP from 10% to 25% in 10 years; encouragement of private enterprise; environmentally sustainable development, conforming to law; ISO 14000 certification encouraged	Increased production/dispersal could increase severity and spread of population problem	Institutional strengthening to enforce environmental rules and regulations. Coordination between DoE and Ministry of Industry is needed
Land: Agricultural land zoning; provisions for leasing of inland open waters; coastal greenbelt creation; participatory forestry on roads	This will support pollution reduction and enrich water environment	Institutional strengthening and coordination is required
Safe Drinking Water Supply and Sanitation (1998): Increased and sustainable basic water supply and sanitation; mitigation of arsenic problems; storm water drainage in urban areas; community participation and social awareness	Surface water quality and groundwater arsenic mitigation are major concern for future	Institutional strengthening, coordination, awareness raising, and ensure community participation
Wetlands (Draft, 1998) Wetlands conservation, sustainable development, and biodiversity conservation; wetlands survey and database maintenance of wetland functions; people's participation in development decisions	Conforms and overlaps with Water Policy; careful definition of wetlands required	Institutional strengthening, coordination, awareness-raising, and ensure community participation

Source: SoE Study Team

3.2.6 OPTIONS AND ACTIONS FOR POLLUTION MANAGEMENT

The Environmental Conservation Acts and Rules, and National Water Policy have adequate clauses related to industrial pollution. This includes water quality protection, institutions to prevent pollution, effluent discharge monitoring, zoning regulations for new industries and strengthening of the regulatory system for agrochemical pollution control.

Under Bangladesh Environment Management Program (BEMP) and Sustainable Environment Management Program (SEMP), the DoE is currently working towards improved water quality monitoring, and estimation of pollution loads in the rivers and watercourses, along with institutional strengthening. The initiatives include preparation of Guidelines for EIA applicable to several sectors, including flood control and drainage. The associated institutional strengthening is also underway. The focus of these initiatives is on ambient water quality monitoring and regulation of proposed new industries. However, there are few initiatives to address the immediate problems, for clean-up programs for the serious industrial pollution caused by existing industries. The DoE have not yet set any guidelines for these in any detail or detail clear time-bound targets. Clear measures for ensuring compliance with the environmental laws and regulations, including enforcement, are lacking. Without clean-up action in and around the main cities, water quality will continue to worsen in the foreseeable future, constituting a major threat to millions of lives and livelihoods, especially of the very poor.

The absolute numbers of polluting industries that have to be dealt with as over 1000 in Dhaka and

Table 3.2.7 A brief description of water quality management options with anticipated outcome and actors

Option	Outcome of the Option	Actors
Land zoning of industries: *Export Processing Zone, Industrial Park etc.*	Support collective treatment of wastes. Reduce pollution load in water ecosystem system	Ministry of Land, Ministry of Industry, Ministry of Environment and Forest and Department of Environment. Private sector and business community
Enforcement: *ECA, ECR, WQS, EIA and environmental audit.*	Help to build institutional capability to deal with rules and regulation. Reduce pollution load and other environmental impacts of industries and other development projects	Ministry of Environment and Forest, Department of Environment, Ministry of Industry, Ministry of Water Resources. Media campaign, NGO actions and campaign on particular issues
Clean-up and Rehabilitation of Pollution Hot-spots: *Dhaka, Chittagong, Khulna etc,*	Make the water available once again for different use and restore habitat for fishes, and other economic activities (e.g. potable water supplies). For example, for Dhaka this would then obviate the need to seek relatively costly unpolluted potable water sources at great distances from the city	Ministry of Environment and Forest, Department of Environment, Ministry of Industry, Ministry of Water Resources. Media campaign, NGO actions and campaign on specific site. Involvement of local community in the clean-up program
Strengthening of Water Quality Monitoring Program: *Nationwide*	Comprehensive water quality data including discharge ('end-of-pipe') and/or identifying the sources of specific pollutants found in receiving waters, water flow in the river course, tidal influence etc	Ministry of Environment and Forest, Department of Environment, Ministry of Industry, Ministry of Water Resources
Maintenance of Dilution and Dispersion Flows in Rivers: *Dry season water flow*	Dilution and dispersion of pollutants in river system will reduce pollution load and concentration	Ministry of Water Resource, Ministry of Environment and Forest, Department of Environment
Sediment Control and Reduction in the Main Rivers	Reduce sediment load in the major river system and subsequently less sedimentation will be found the floodplain	Internationally coordinated action is required to reduce soil erosion in the upper catchments. Activities can be canalized through Joint River Commission, Ministry of Water Resource
Waste reception and treatment facilities in ports: *Chittagong and*	Enable port to receive bilge and ballast water for treatment. Reduce pollution load in the coastal area	Ministry of Shipping and Port Authority
Strengthening of Coast Guard Ships	Enable to detect oil and lube oil spillage	Ministry of Shipping and Port Authority
Study of Bio-accumulation	Enable to detect accumulation of harmful substances in aquatic species and its health hazards	Fisheries Department of Fisheries, Department of Environment, Ministry of Health
Study on Agrochemicals Residues in Water	Enable to detect residues of agrochemicals in water ecosystem	Department Environment, Department of Agriculture

Source: SoE Study Team

over 600 in Chittagong alone. It is suggested that no realistic strengthening and expansion of the DoE will be able to cope directly with all the problems. Therefore, an essential component of any pollution clean-up strategy must be through mobilization of other organizations and the public in generag, including public-private partnership approaches. The supporting measures must allow concerned groups or even ordinary citizens to have legal access to redress water pollution problems.

The following options may be put forward to address the requirements of the National Environment Policy and National Water Policy. A brief description of water quality management options, which could be considered separately or in a combined manner, with their anticipated outcomes, and possible actors, is presented in Table 3.2.7.

To address water pollution and scarcity problems through undertaking various options mentioned above needs institutional coordination, strengthening, and strategies for obtaining research and study funds from the international donor community.

3.2.7 CONCLUSION

Water resources need to be managed both qualitatively and quantitatively due to their importance for economic development, and the physical and social environments. Particularly in Bangladesh, where water is intricately linked with the lives of people and economy, its value has increased with competing demand. Therefore, economic efficiency of water use is a major policy consideration. Frequent floods and droughts in Bangladesh impose tremendous variability, and make it difficult to manage development based on prices and the market mechanism. The Government of Bangladesh is facing a number of growing problems, because it cannot address water issues in a comprehensive manner. Separate ministries and departments are in charge of pollution control, surface irrigation, groundwater irrigation, fisheries, public health, environment, municipal water supply, power and navigation, and each acting independently. The interdependency among sub-sectors and uses should be recognized and comprehensive planning, taking the interest of all users into account, should be used to reduce the conflicts in the system.

MoEF and DoE are burdened with the tasks of (a) setting standards, (b) evaluating and giving clearance to impact assessments, and (c) enforcing environmental rules and regulations. These are major tasks, and although institutional strengthening of DoE is underway to help develop its capacity to fulfill its mandate. The task would become easier if other agencies fulfilled their own environmental duties and responsibilities effectively. The role of civil society as a whole would be made significant by their meaningful participation in environmental issues, and help in tackling the problems, through public-interest litigation.

Major agencies with activities in the water sector, such as BWDB, LGED and DWASA, have environmental guidelines for developing and implementing their projects. However, there is a lack of relevant skills in these organizations. LGED has established an environmental cell, but BWDB has not done it yet where usually working on outsourcing EIA work for larger projects. A general training on environmental awareness, and empowerment to take action would contribute greatly to raise environmental standards.

Current legal frameworks require all implementing agencies to conform to environmental rules and standards, but without a strong support from DoE and proper resources, the quality of the EIAs undertaken cannot be assured. In addition, future climate change issues have emerged that particularly the national water sector has included in planning for development and management of water resources.

References

Ahmed, A.U. and Reazuddin, M. (2000) Industrial Pollution of Water Systems in Bangladesh, In Rahman, A. A., Huq, S. and Conway, G.R. (ed), *Environmental System of Surface Water Systems of Bangladesh*, University Press Limited, Dhaka, Bangladesh pp 175-178.

Ayers, R.S. and Westcot, D.W. (1976) *Water quality for agriculture*. Irrigation and Drainage Paper 29, FAO, Rome.

BARC (1981-82) *Second Annual Report*. Co-ordinated irrigation and water management project. Bangladesh Agriculture Research Council (BARC) Soils and Irrigation Publication No. 10. Dhaka.

BARC (1982-83) *Third Annual Report*. Co-ordinated irrigation and water management project. Bangladesh Agriculture Research Council (BARC) Soils and Irrigation Publication No. 12. Dhaka.

BBS (1979) *Statistical Year Book of Bangladesh*, Bangladesh Bureau of Statistic, Ministry of Planning, Dhaka, Bangladesh.

BBS (1985) *Statistical Year Book of Bangladesh*, Bangladesh Bureau of Statistic, Ministry of Planning, Dhaka, Bangladesh.

BBS (1990) *Statistical Year Book of Bangladesh*, Bangladesh Bureau of Statistic, Ministry of Planning, Dhaka, Bangladesh.

BBS (1992) *Statistical Year Book of Bangladesh*, Bangladesh Bureau of Statistic, Ministry of Planning, Dhaka, Bangladesh.

BBS (1994) *Statistical Year Book of Bangladesh*, Bangladesh Bureau of Statistic, Ministry of Planning, Dhaka, Bangladesh.

BBS (1998) *Statistical Year Book of Bangladesh*, Bangladesh Bureau of Statistic, Ministry of Planning, Dhaka, Bangladesh.

BCAS (2000) *Pollution Study*, Management of Aquatic Ecosystem through Community Husbandry (MACH), Dhaka, Bangladesh.

Bhumbla, D.R., Singh, B. and Singh, N.T. (1968) Effect of Salt on Seed Germination. *Indian. J. Agron*. 13, pp 181-185.

BRRI (1983) *Annual Internal Review on Plant Physiology*. Bangladesh Rice Research Institute (BRRI), Joydevpur, Bangladesh.

Chowdhury, K. R., Alam, A.m S., Shamsuddin, S. D., Shakhawat, H. and Haque, S. (1994) A Preliminary Assessment of Water and Sediment Pollution Load Along the Coasts of Chittagong and Cox's Bazar, *The Journal of NOAMI, Vol 11, No. 2*, December 1994.

Coleman, J.M. (1969) *Brahmaputra River: Channel Processes and Sedimentation*. Sedimentary Geology, B129-239.

Das, S.K. and Mehrotra, C.L. (1971) *Salt Tolerance of Some Agricultural Crops during Early Growth Stages. Indian. J. Agric. Sci*., 41, pp 882-888.

DoE (1993) *Water Quality Data of Rivers Buriganga, Meghna, Balu, Shitalakhya, Jamuna (1981-90)*, Department of Environment, Dhaka, Bangladesh.

DoE (1997) *Survey on Ship Breaking Industries and Water Quality in Chittagong Region* (unpublished), Dhaka, Bangladesh

DHV (1998) *Meghna Estuary Study*, Draft Master Plan, Volume 1, Main Report for BWDB, Dhaka, Bangladesh.

EEA (1999) *Environment in the European Union at the turn of the Century*, European Environment Agency, Copenhagen, Denmark.

Haque, B.A. (1998) *Biological Contamination of Tube well Water*, ICDDRB, Bangladesh

Hossain (2000) *Personal communication*, Bangladesh University of Engineering and Technoloyg, Dhaka, Bangladesh.

Hossain, M. M. (2000) Pollution Problem in the Costal Area of Bangladesh, *Oceanography*, No. 4&5 Vol. L pp. 21-26

Hossain, M. M. (1992) Total Sediment Load in the Lower Ganges and Jamuna, *Journal of IEB*, Vol. 20 No. 1&2 pp. 1-8

Islam, M.N. 1986, Alternative Adjustment to Natural Hazards; Implication for Bangladesh, *Presidential Address at the 11th Annual Bangladesh Science Conference*, Rajshahi, Bangladesh.

Majumder, M.K. (1999) What has Gone Wrong with the Bay, In Chowdhury K.I (ed), *Bangladesh State of Environment Report 1999*, FEJB, Dhaka, Bangladesh.

Milliman, J.D. and Meade, R.H. (1983) World-wide Delivery of River Sediment to the Oceans. *J. of Geol*., 91, pp 1-21.

Nazem, N.I and Kabir, M.H. (1986) *Indo-Bangladesh Common Rivers and Water Diplomacy* (BIISS paper-5)

Rahman, M. Md. (October 2000) *Low-Flow Criteria for Water Quality Standards for Selected Rivers* (Masters Thesis), Department of Engineering and Technology (BUET), Dhaka, Bangladesh.

Rai, M. (1977a) Salinity Tolerance in Indian Mustard and Sunflower. *Indian J. Agric. Sci*., 47, pp 70-73.

Rai, M. (1977b) Varietal Resistance to Salinity Tolerance in Maize. *Indian J. Pl. Physiol*., 20, pp 100-104.

Saad, M. S. (2000) *Personal Communication*, Surface Water Modelling Centre (SWMC), Dhaka, Bangladesh.

WARPO (1999a) *Topic Paper 4*, National Water Management Plan Project, Ministry of Water Resource, Government of Bangladesh.

WARPO (1999b) *Topic Paper 7*, National Water Management Plan Project, Ministry of Water Resource, Government of Bangladesh.

WARPO (2000a), *Annex G: Environment*, National Water Management Plan Project, Ministry of Water Resource, Government of Bangladesh.

WARPO (2000b) *Main Report, Volume No. 2*, National Water Management Plan Project, Ministry of Water Resource, Government of Bangladesh.

Yusuf, H. K. M. (1998) *Impact of the 1998 Flood on Water Quality in Dhaka City*, Draft Report, Department of Environment, Ministry of Environment and Forest, Dhaka, Bangladesh.

3.3.1 INTRODUCTION

Air is indispensable for the survival of all living organisms on earth, including human beings. It is even more important than water - without water a person can survive for days, but without air no more than a couple of minutes.

Air pollution is one of a variety of manmade environmental disasters that are currently taking place all over the world. Air pollution may be defined as an atmospheric condition in which various substances are present at concentrations high enough above their normal ambient levels to produce a measurable effect on people, animals, vegetation, or materials. 'Substances' refers to any natural or manmade chemical elements or compounds capable of being airborne. These may exist in the atmosphere as gases, liquid drops, or solid particles. It includes any substance whether noxious or benign; however, the term 'measurable effect' generally restricts attention to those substances that cause undesirable effects.

Recently, air pollution has received priority among environmental issues in Asia, as well as in other parts of the world. Exposure to air pollution is the main environmental threat to human health in many towns and cities. Particulate emission is mainly responsible for increased death rate and respiratory problems for the urban population. This problem is acute in Dhaka being the capital of the country and also the hub of commercial activity. The other urban areas i.e. Chittagong, Khulna, Bogra and Rajshahi have much lesser health problem related to urban air pollution. The ambient atmospheric conditions have progressively deteriorated due to the unprecedented growth in numbers of motor vehicles, and continuous housing and industrial development.

Bangladesh is one of the least developed agrarian nations in the world. However, since it's birth in 1971, there has been some growth in the industrial sector. Industries are mainly concentrated in major urban areas like Dhaka (the capital), the seaport cities like Chittagong and Khulna, the inland port city Narayanganj, and other divisional towns. Naturally, the air pollution problem is more acute in these areas. Apart from unplanned industrial development in these areas, the severity of the pollution is increased mainly due to exhausts from two-stroke engine and diesel-run vehicles.

In the rural areas of Bangladesh, the air pollution problems have not yet become a point of concern. This is due to fewer motorized vehicles and industries in rural areas. The principal sources of emission in the rural areas are from brick kilns, and from cooking stoves. In rural areas, wood, coal, and bio-mass are used as sources of energy. Thus, it is likely that in rural areas the principal air contaminants are particulate matter and volatile organic compounds (VOCs). During the monsoon, rural people cook inside their houses without adequate ventilation systems. This give rise to severe indoor air pollution which adversely affects their health, particularly of women and children.

3.3.2 PRESSURES

Air quality has deteriorated both due to human activities, and natural phenomenon such as wind blown dust particles etc. There are two major sources of air pollution in Bangladesh, vehicular emissions and industrial emissions. However, these are mainly concentrated in the cities. Other than that there are numerous brick-making kilns used seasonally (in dry season) all over Bangladesh. Almost all of these kilns use coal and wood as their source of energy, resulting in the emission of particulate matter, oxides of sulfur, and volatile organic compounds. In addition to these usual sources of fuel, spent or used rubber wheels of vehicles are also burnt, which emit black carbon and toxic gases. These are hazardous for health. The emissions caused by these sorts of practices sometime exceed the mechanisms for the natural rate of purification of the local atmosphere giving rise to severe episodes of local air pollution.

Per capita energy consumption in Bangladesh is increasing with time, which affects the air quality indirectly. In Bangladesh from 1972 to 1980, per capita consumption of commercial energy increased from 24 to 32.8 kilogram oil equivalent (KOE). It grew to 41.3 KOE in 1985, and 56 KOE in 1989- 90. The total per capita energy consumption of Bangladesh in 1989-90 stood at 164 KOE, where commercial energy accounts for 34.6 per cent of the total energy used in the country. The rest is from non-commercial resources like agricultural waste, fuel wood, cow dung, etc. Table 3.3.1 depicts interlinks of pressures, states, impacts, and policy responses regarding air pollution. Detailed program responses are discussed in Section 3.3.5.

Table 3.3.1 Pressures, State, Impacts, and Responses to Air Pollution

Pressures	State	Impacts	Policy Responses
1. Urbanization	Increase in vehicle emission	Urban air quality deterioration	Bangladesh Environmental Conservation Act (ECA), 1995, and Environment Conservation Rules, (ECR), 1997
2. Industrial Pollution	Emission of SO_2, NO_x, Pax, Gases, Vapours	Air quality deterioration • Harmful for human health. • Plant quality and growth affected • Corroded building materials • Ecosystem disturbed	Bangladesh ECA '95 and ECR '97 More stringent enforcement of ECA and ECR enabled through capacity building of DOE
3. Emissions from Vehicles	PM, CO, NO_x, SO_2, VOC	• Human health hazard • Plant quality and growth affected • Corroded Building Materials • Ecosystem disturbed	Bangladesh ECA '95 and ECR '97
4. Brick fields and kilns	PM, CO, NO_x, SO_2	Health Hazard	The Brick Burning (control) Act, 1989 & The Brick Burning (control) Amendment Act 1992, Bangladesh ECA '95 and ECR '97
5. Building Construction	PM	Health Hazard	Bangladesh ECA '95 and ECR '97
6. Open dumping of Wastes for disposal	Gases, Vapour, Odors	Air quality deterioration	Bangladesh ECA '95 and ECR '97
7. Wood/Biomass/ Coal Consumption	PM, VOC, SOx	Health Hazard	
8. Fuel quality	VOC + others	Health Hazard	

Source: SoE Study Team

3.3.2.1 Rapid Urbanization

Urbanization is an inherent part of the process of economic development in Bangladesh, and its rate can be indicated by the large population growth in urban areas. In 1981 the total population in urban areas was 14.08 million, which increased to 22.45 million in 1991. With increased urbanization, the number of vehicles is also increasing rapidly, and contributing to more and more air pollution. The major urban centers in the country are the metropolitan cities of Dhaka, Rajshahi, Khulna and Chittagong. Dhaka, the capital of Bangladesh is one of the most densely populated cities in the world. This is the center for the major economic and commercial activities, too.

In the urban areas ambient air quality is dependent on many factors like air movement, traffic volume, congestion, emissions from motor vehicles, and resuspended dust particles. Various other activities related to the extremely high population density also result in severe air and other forms of pollution. The salient parameters of air pollution are suspended particles, sulfur oxides, nitrogen oxides, hydrocarbons, carbon monoxide, lead, ozone and other gases.

Aircrafts, railway engines, power plants, open-burning incineration, solid waste disposal sites, and dust particles also contribute to air pollution. Dust pollution due to road diggings, constructions and other development activities further aggravate the air pollution situation in cities. In order to accommodate the growing population, the construction of multi-storied buildings is increasing rapidly. Along with these buildings, the number of slums are also increasing. The tremendous pressure of population has made it almost impossible to maintain a clean environment in the capital city of Dhaka.

3.3.2.2 Emissions from Vehicles

Due to rapid and unplanned urbanization the total number of vehicles has increased enormously. Most of the cars, jeeps, auto-rickshaws, motorcycles, etc., ply in the cities. This has really led to a deterioration of air quality, particularly in Dhaka. Table 3.3.2 shows the different types of automotive vehicles plying in Dhaka, which indicates their rate of growth (BBS, 1997a).

Although the percentage of two stroke auto-rickshaws is around 8 per cent, some recent studies have shown that they contribute around 40 per cent of PM10 and 50 per cent of HC in Dhaka City. The second largest polluters are trucks and buses, although they constitute only 10 per cent of the total automotive vehicles in Dhaka. These cause about 44 per cent of the PM10 pollution.

The Department of Environment, and other concerned agencies and organizations, have identified the two-stroke engines used in auto-rickshaws, tempos, mini trucks, and motorcycles as major polluters. These vehicles with two-stroke engines have the worst emission levels of all types vehicles. As present, there are about 65,000 baby taxies among the more than 296,000 motor vehicles that ply in Dhaka city alone.

In a survey conducted by the Bangladesh Road Transport Authority (BRTA), it was found that the

Table 3.3.2 Types of Automotive Vehicles in Dhaka

Date	Car/Jeep/Stn. Wgn.	Scooter/M. Cycle	Autorickshaw	Tempo & Others	Buses	Goods Vehicles	Total
Apr-71	16,289	9,644	3,843	888	1,531	3,640	35,835
Apr-72	17,165	10,265	3,851	1,086	1,714	4,027	38,108
Apr-73	18,018	11,486	4,680	1,086	2,078	4,424	41,772
Apr-74	19,081	12,957	5,065	1,086	326	4,711	45,226
Apr-75	20,128	14,433	5,065	1,107	2,495	4,998	48,226
Apr-76	20,606	16,582	5,161	1,110	2,534	5,309	51,302
Apr-77	22,140	17,916	5,324	1,120	2,560	5,391	54,451
Apr-78	24,223	19,754	5,688	1,168	2,753	5,672	59,258
Apr-79	25,986	19,936	5,765	1,228	2,884	5,903	61,702
Apr-80	28,692	22,946	6,318	1,587	3,493	6,631	69,667
Apr-81	31,443	26,756	6,786	1,605	3,695	7,156	77,441
Apr-82	33,840	29,372	6,902	1,630	3,843	7,566	83,153
Apr-83	35,666	32,184	6,982	1,733	4,003	7,907	88,475
Apr-84	38,124	37,782	7,098	1,849	4,255	8,325	97,433
Apr-85	41,650	46,396	7,256	1,969	4,418	9,103	110,792
Apr-86	44,167	53,454	8,147	2,303	4,542	9,610	122,223
Apr-87	47,346	58,467	10,016	3,051	4,798	10,095	133,773
Apr-88	50,660	62,733	11,100	3,733	4,892	10,740	143,858
Apr-89	53,394	66,265	12,433	4,219	5,032	11,124	152,466
Apr-90	55,548	69,063	14,015	4,508	5,217	11,246	159,596
Apr-91	58,243	72,412	15,626	4,677	5,427	11,324	167,708
Apr-92	60,529	76,537	17,736	4,779	5,695	11,958	177,233
Apr-93	63,695	79,550	19,802	5,020	5,911	12,601	186,578
Apr-94	69,058	82,739	25,523	5,327	6,385	13,727	202,758
Apr-95	75,740	85,245	32,433	5,753	6,910	15,020	221,101
Apr-96	83,965	87,282	41,153	6,285	7,538	16,559	242,784
% in 1988	35%	44%	8%	3%	3%	7%	100%

Source: BBS, 1997a

Black smocks emitted from the vehicles does not bother road side food venders

two-stroke petrol engines are less fuel-efficient, and emit about 30-100 times more unburned hydrocarbons than four-stroke engines; and diesel engines emit 13 times more smoke than non-diesel four-stroke engines.

The automobiles on the roads are often very old, overloaded, and poorly maintained. Other old vehicles, including 40-year old trucks and dilapidated mini-buses, are also plying the city streets emitting smokes and gases. According to an assessment made by DoE, 90 per cent of the vehicles that ply Dhaka's streets daily are faulty, and emit smoke far exceeding the prescribed limit. Black smoke which is primarily unburned fine carbon particles is emitted by diesel vehicles. Table 3.3.3 indicates the low numbers of vehicles that are actually fit to be driven according to the Government standards for emissions versus the total numbers.

3.3.2.3 Unplanned Industrial Development

Industrial development is another source of air pollution. Industries in Bangladesh are situated mainly in major urban areas, particularly in Dhaka, Chittagong, and Khulna. Accordingly, air pollution is concentrated mainly in these cities. Table 3.3.4 indicates that the total number of manufacturing industries in Bangladesh increased about 11 per cent over the 4 years between 1988-1989 and 1991-1992 (BBS, 1997b). However, as the data includes only the recorded industries, the actual number of industries is expected to be much higher.

Textile and dyeing, tanneries, pulp and paper, cement, metal, fertilizer, and chemical factories in particular emit PM, sulfur oxides, nitrogen oxides, carbon monoxide, and ammonia, all of which deteriorate air quality. The geographical distribution of different industries is given in Table 3.2.2 in the Water Pollution and Scarcity section of the report.

Table 3.3.3 Good Quality Vehicles Numbers from 1981 - 1996

Year	Total vehicles number	Good vehicles number	Percentage of Good vehicles
1981	77,441	7156	9.2
1986	122,223	9610	7.8
1991	159,596	11,124	6.9
1996	242,784	16,559	6.8

Source: BRTA

Table 3.3.4 Growth in Industrialization for the period 1988-1992

Year	Number of Reporting Industries
1988-89	23,752
1989-90	25,283
1990-91	25,890
1991-92	26,446

Source: National Action Plan for Air Pollution, 1999

3.3.2.4 Brick Kilns

Brick-making kilns, of which the majority are of the conventional type, use coal and wood as their source of energy. This is mainly due to the non-availability of natural gas in most parts of Bangladesh. The air pollution from these kilns is not only due to the type of fuel used, but also due to the thermal inefficiencies of the conventional kilns. This causes emissions like SO_x, CO, particulate matters, and volatile organic compounds that deteriorate air quality. Another significant factor is that brick kilns are usually clustered near big cites in various parts of Bangladesh. Therefore, the parts of the city in the immediate vicinity of the clustered brick-fields have serious air pollution problems.

3.3.3 STATE OF AIR POLLUTION

A continuous monitoring scheme is essential to evaluate air quality and for the development of any

Air and water pollutions from unplanned industries

plan for mitigation of health risks caused by polluted air. The six "criteria pollutants", particulate matter (PM 10, PM 2.5), CO, SO_2, NO_x and ozone have to be monitored more or less continuously at a reasonably large number of locations. Other pollutants (e.g., ammonia, hydrocarbons, lead, carbon dioxide, etc.) should also be measured, where their levels are considered to be significant.

Again, the salient problems in the cities of Bangladesh are not like those in other developed countries. The developed countries are able to manage these problems, but in Bangladesh cost is a major criteria. There is also a general lack of expertise to evaluate the problems, or prepare cost-effective solutions, and therefore, the air quality is not yet managed effectively.

Monitoring of ambient air quality in Bangladesh is a very recent phenomenon, initiated on a very limited basis by DoE using high volume samplers, with the help of development partners. However, the acuteness of the problems caused by air pollution, and awareness campaigns organized by different mass media, have made the government aware of the necessity of monitoring ambient air quality. Accordingly, the Department of Environment has set up four monitoring stations at four divisional towns, namely, Dhaka, Chittagong, Khulna, and Bogra. Monitoring has been done mostly in Dhaka at various places, and samples collected analyzed for the three pollutants SPM, SO_2, and NO_x. Very limited monitoring has also been done at Chittagong for these three parameters. In addition to monitoring through these stations, the DoE conducts vehicular emission measurements in Dhaka cityoccasionally. In Dhaka City, the locations are: Tejgaon, Farmgate, Manik Mia Avenue, Gulshan, Lalmatia, and Agargaon. These areas represent industrial, commercial, and residential areas of the city.

In addition to DoE, a number of other organizations are monitoring air quality, as well as emissions from automobiles. The Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET) has been conducting ambient air quality surveys since 1995. The most recent one, conducted by the Department of Civil Engineering over a prolonged period in 1998, includes the measurement of SO_x and NO_x at 14 different locations of Dhaka city at different times of the day.

The air quality standards are different for residential, industrial, commercial, and sensitive areas. According to various studies the worst affected areas in Dhaka city include: Hatkhola, Manik Mia Avenue, Tejgaon, Farmgate, Motijheel, Lalmatia, and Mohakhali. Surveys conducted between January 1990 and December 1999 showed that the concentration of suspended particles goes up to as high as 3000 micrograms per cubic meter (Police Box Farmgate Station, 1999 December), although the allowable limit is 400 micrograms per cubic meter. The nitrogen oxides concentrations at these spots (maximum of 77 micrograms per cubic meter) were below the permissible limit. The sulfur dioxide in the air near Farmgate was found to be 385 micrograms per cubic meter, which is higher than the maximum permissible limit of 100 micrograms per cubic meter. In the Tejgaon Industrial Area

the maximum concentration of SPM was 1849 micrograms per cubic meter (Jan 1997), as opposed to the allowable limit of 500 micrograms per cubic meter. The maximum concentration of air pollutants in Dhaka was during the dry months of December to March, according to a survey conducted by DoE.

The increase in emission of different pollutants over the period 1985 to 1995 is shown in Table 3.3.5. The increase in SPM, SO_2 and NO_x emissions in Dhaka is alarming, and the air quality is obviously deteriorating with time. The air quality in the secondary cities and towns was comparatively better.

The DoE has published air quality data in terms of concentrations of SPM, NO_x and SO_2 in Dhaka City. The increase in concentrations of these pollutants over the last four years is shown in Table 3.3.6 and Figure 3.3.1 shows the seasonal variation of pollutants concentration in the framgate area in the Dhaka City.

Table 3.3.5 Emission Rate (ton/day) Of Different Pollutant Particles In Dhaka City

Year	SPM	SO_2	NO_x	CO	HC	CO_2
1985	4	2	30	118	29	3037
1990	5	3	37	157	42	3885
1995	7	3	44	205	59	4828

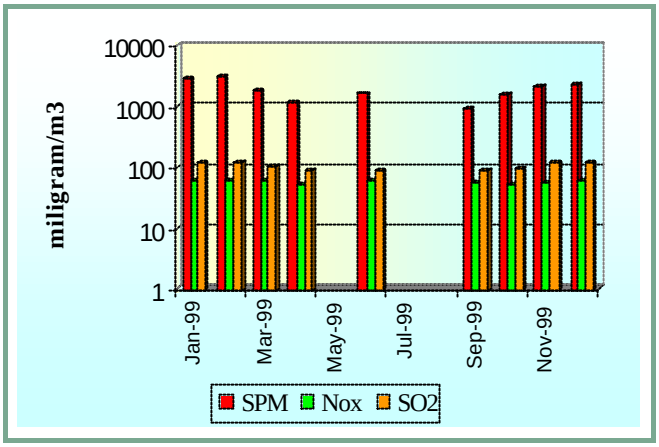
Source: DoE, 1999.

Table 3.3.6 Air Quality of Farmgate area

Pollutant	Dec 1996	Dec 1997	Dec 1998	Dec 1999
SPM µgm/m3	2080.41	1659.6	2485.26	2300.35
NO_xµgm/m3	27.17	41	66.5	58.1
SO_2 µgm/m3	15	66	146.19	121.3

Source: DoE, 2000

Figure 3.3.1 Monthly Variation of Concentration of Pollutants at Farmgate area



Source: DoE, 2000

The Farmgate area was chosen for monitoring because it has among the highest number of vehicles passing through it. Therefore, these figures reflect the upper limit of pollution.

Recently, BAEC reported results from a study on the nature and extent of air pollution in urban and

Table 3.3.7 Average Suspended Airborne Particulate Matter (µg/m^3) during the Collection Periods in Urban Areas of Bangladesh

Location		Coarse (PM 2.5-PM 10)		Fine (PM 2.5)	
		Average	SD	Average	SD
Urban: Dec. '96 - June '98	LRF	68.5	38.5	73.5	25.5
	MRF	61.9	42.3	41.2	22.1
	HRF	27.1	10.3	36.2	23.2
	Overall	58.4	39.9	51.7	27.6
Urban: Aug. '93 - June '94	LRF	139	67	88.0	47.0
	MRF	42.0	28.0	34.0	16.0
	HRF	13.1	4.7	16.8	4.8
	Overall	72.0	69.3	50.7	42.9
Urban: Jan. '95 - Jan. '96	LRF	63.2	23.1	35.1	9.9
	MRF	41.9	37.0	23.7	10.2
	HRF	10.9	4.9	12.2	3.9
	Overall	35.0	32.9	21.1	10.7

Note: LRF- Low rainfall period; MRF- Medium rainfall period; and HRF- High rainfall period

Table 3.3.8 Average Elemental Carbon (μg/m^3) in the Fine Fraction of Airborne Particulate Matter during the Collection Periods in Urban And Rural Areas of Bangladesh

Location	Overall		LRF		MRF		HRF	
	Average	SD	Average	Average	Average	SD	Average	SD
Urban: Aug. '93 - Dec. '94	17.30	16.26	32.33	19.32	10.24	03.32	06.60	01.48
Urban: Dec. '96 - Jun. '98	19.45	10.47	25.64	08.89	18.82	10.14	08.81	02.34
Rural: Jan. '95 - Jan. '96	07.08	03.76	11.00	03.37	07.62	04.31	04.20	01.29

Note: LRF- Low rainfall period; MRF- Medium rainfall period; and HRF- High rainfall period

rural areas of Bangladesh during 1993-1998. This study was based on the realization that from the point of view of health effects, the particle size of Airborne Particulate Matter (APM) is important, as well as its suspension time in air, and hence extent of long distance transportation. In 1993, as part of an internationally coordinated research program by International Atomic Energy Agency (IAEA), BAEC started work on the analysis of the size fractionated APM. Size fractioned samples were collected from both rural and urban areas of Bangladesh over a period of three years. The average mass load in the air during the low rainfall period (LRF) for both fine and course fractions during 1997-98 has been published. It was found that the mass loads of both the APM of particulate mass PM 10 and PM 2.5 were higher that USEPA and WHO standards.

In a paper by M. Khaliquzzaman, S.K. Biswas, S. A. Tarafdar, and A. Islam, at the Mid-Term Review Meeting on 'Air Pollution and Its Trends' (Singapore, October 18-22, 1999), results were presented on the average air particulate mass during the collection period in rural and urban areas of Bangladesh, and average elemental carbon in the fine fraction of airborne particulate matter in these areas. The results are shown in Table 3.3.7 and 3.3.8. Results from monitoring the quality of air in urban areas showed that the concentration of suspended particles in ambient air is many times higher than normal. The conclusion was that the PM 2.5 masses and chemical concentrations are lower in most cases compared to the corresponding PM 2.5- PM 10 values. The ratio of PM 2.5 to PM 10, and the amount of black carbon in the APM are reduced during the high rainfall (HRF) period in both rural and urban sites by about 25 per cent and 20 per cent, respectively.

The Bangladesh Atomic Energy Commission (BAEC) and the Bangladesh Council of Scientific and Industrial Research (BCSIR), in association with the DoE, recently conducted research studies primarily aimed at measuring the concentration of lead in the ambient air. The Dhaka Shishu (Children's) Hospital also conducted research in association with the BAEC on the level of lead in the blood of children of Dhaka city, and also studied the possible impact of leaded gasoline on them. The Bangladesh Road Transport Authority (BRTA) is also setting up a vehicle emission monitoring station at Mirpur, Dhaka.

The survey conducted by the scientists of Bangladesh Atomic Energy Commission (BAEC) prior to introduction of unleaded gasoline showed that the air that city dwellers breathe on the roads contains lead in concentrations almost ten times above the government safety standard set by the DoE. The BAEC study found alarmingly high quantity of lead in the air of Dhaka city which was 463 nanograms per cubic meter - the highest in the world. Figures for lead concentrations in other major cities in the world, in nanograms per cubic meter as reported in the same report were 383 in Mexico City, 360 in Bombay, and only 70 in Los Angeles.

The Department of Environment also conducted a study for lead levels in three different areas of Dhaka city, from November 96 to March 97. They found the level to be 123-252 nanograms per cubic meter at Farmgate area, and 61 to 76 nanograms per cubic meter in Tejgaon Industrial area.

However, during July 1999 the GoB executed the decision to provide only unleaded gasoline in the country. According to recent measurements between late 1999 and 2000 by BAEC and Eastern Refinery Ltd (ERL), the gasoline dispensed at pumps in

Bangladesh is now confirmedly free of lead (Shah *et. al.*, 1999). However, measurements on lead levels in ambient air after introduction of unleaded gasoline are still not available.

This is a classic example of heightened awareness campaigns initiated by civil society (see box).

UNLEADED GASOLINE IN BANGLADESH – A MAJOR SUCCESS STORY

On July 1, 1999, the Government of Bangladesh executed the landmark decision of providing only unleaded gasoline. According to recent measurements by the Bangladesh Atomic Energy Commission and Eastern Refinery (late 1999 and early 2000) have confirmed that gasoline dispensed at pumps in Bangladesh is now free of lead By going lead-free virtually overnight, Bangladesh has become a model for other countries in the developing world that are working to eliminate the harmful pollutant from gasoline.

Lead is a major environmental health hazard and is the number one environmental disease among young children in developing countries, according to the World Bank, which has been providing technical assistance to the Government of Bangladesh and other countries the lead phase-out issue.

The full impact of lead poisoning on the health of children and adults is becoming clearer to most countries, and many governments have begun to take action. Bangladesh joins the ranks of countries such as the US, UK, Germany, and Thailand that have taken aggressive steps to combat lead poisoning, which has resulted in significant health and economic benefits in the countries. In developing countries, however, actions have been slower and sporadic.

How it was done in Bangladesh

The problem of lead pollution in the capital city Dhaka was identified as early as 1980. However, little data was available until 1991 when high levels of lead in samples of suspended particles in air were reported. The chemical analysis of the samples clearly identified the presence of lead and their gasoline origin. In 1995 the need to address lead pollution was raised by different government agencies, environmental and health advocates and international organizations such as the IAEA and the World Bank. The issue received considerable attention in seminars, symposia, and the press, and the options for introducing unleaded gasoline were discussed with the Eastern Refinery, Chittagong which is the only installation producing petroleum products in the country.

Heightened awareness of the dangers of lead pollution prompted the agencies concerned with the production and marketing of petroleum products and the Ministry of Energy to begin taking action. In 1997, lead content was reduced from 0.8 g/liter in the 1980s to an average of 0.4 g/liter by blending locally refined leaded gasoline with imported unleaded gasoline. In 1998, low octane gasoline was made lead free, but high octane gasoline still contained 0.4 g/liter of lead. The increasing share of unleaded gasoline was achieved by importing only unleaded gasoline to make up for the difference between domestic supply and demand. Growing public pressure encouraged the National Environment Council to adopt a resolution to switch to unleaded gasoline in 1998, and subsequently the Ministry of Energy made the decision to go lead free last year.

Recently, Prof. Abul Hussam of George Mason University, Virginia, USA, (August, 1998), detected 200 organic compounds by analyzing four air samples collected from the Shewrapara area of the city, and identified 35 of them.

One emerging problem is the ground level ozone pollution level in urban areas. This major component of "smog" forms when oxides of nitrogen and volatile organic compounds (VOCs) chemically react in warm temperatures and sunlight. Ground level ozone can create a serious health hazard. It can exacerbate the symptoms of asthma, cause significant damage to lung cells, and reduce the ability of lungs to fight infection.

Transboundary Air Pollution

It can be said with certainty that there is trans-boundary pollution from our neighboring countries, because of the seasonal variation in wind direction. No data on this topic is yet available as there are no suitably located monitoring facilities for the purpose. However, recently UNEP has taken an initiative to set up a few monitoring stations. After ascertaining the extent of trans-boundary pollution, policies for mitigation can be developed in cooperation with neighboring countries.

3.3.4 IMPACTS OF AIR POLLUTION

Areas in the South Asian region undergoing rapid urbanization and industrialization are now

experiencing unacceptable air quality, and rapid growth of vehicle numbers. A person inhales an average of about 16 m^3 of air per day, and thus its quality is obviously a concern for humans, as well as other living beings. Acceptable ambient air quality is also required for preserving structures and historical monuments. Air pollutants lead to acid rain falling on forests, crops and aquatic ecosystems, which compromises their condition. The country has a few studies on the impacts of air pollution on human health, and virtually no study on its impacts on ecosystems, livestock, and vegetation. The following Table 3.3.9 shows the pollutant sources and the impacts of air pollution in a broader context, highlighting international findings.

3.3.4.1 Impacts on Human Health

According to the World Health Organization, health is a "state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity". The air we breathe not only has life-supporting properties, but also life-damaging properties, particularly when the balance among the air components is disturbed, or otherwise becomes polluted. All the impurities in inhaled air do not necessarily cause harm. The prime factors affecting human health are the nature of a pollutant, concentration of pollutants, duration of exposure, and the state of health and age group of recipients.

A descriptive cross sectional study on lead levels was conducted in selected areas of Dhaka city by a

Table 3.3.9 Pollutants, Sources, and the Impacts of Air Pollution

Pollutants	Sources	Impacts
1. Suspended Particulate Matter (SPM)	Motor vehicles Wood-burning Industrial activities	Respiratory infection Throat irritation Aggravated asthma
2. Sulfur Oxides	Vehicles (diesel-using) Factory emissions	Affect respiratory tract and permanent lung damage Bronchitis Emphysema Asthma Plant growth reduction Beans and tomatoes with bleached colorless spots
3. Nitrogen Oxides	Vehicle motors Power stations	Respiratory diseases Chest congestion Eye irritation Headache Suppressed growth of beans and tomatoes Increase abscission and reduce yield in citrus plants Spots and mild necrosis on cotton and bean plants Acute leaf failure
4. Lead	Windblown dust Vehicles Coal & wood-burning Metal production Phosphate fertilizer	Affected central nervous system Renal damage Hypertension Children are 3 times more at risk than adult Effects on plants
5. Carbon Monoxide	Petrol vehicles (2 and 3 wheelers)	Reduces the ability of blood to carry oxygen Exacerbates heart disorders
6. Aromatic Hydrocarbons	Unburned fuel from diesel engines	Drowsiness Eye irritation
7. Benzene	Unleaded petrol Emitted from catalytic converters	Carcinogen Affected central nervous system
8. Ozone	Reaction between VOCs and NO_X in presence of sunlight	Reduced lung function Asthma Eye irritation Nasal congestion Lowered resistance to infection

Source: Philip Gain, 1998

researcher at the Department of Occupational and Environmental Health, NIPSOM, on rickshaw pullers, baby-taxi drivers, traffic police, tempo assistants, and petrol pump operators (NIPSOM, 2000). The study found that the mean blood lead levels were: rickshaw pullers 248 micrograms/dl (range 154-344 micrograms/dl), baby-taxi drivers 287 micrograms/dl (range 161-372 micrograms/dl), traffic police 272 micrograms/dl (range 152-32 micrograms/dl), tempo assistants 255 micrograms/dl, and petrol pump operators 249 micrograms/dl (mean 207-342 micrograms/dl). The mean blood lead level among these risk groups was found to be higher than the acceptable value, with traffic police being the worst affected group. The study also noted that blood lead levels increased with duration of exposure.

Most recently lead poisoning has been found in children at the Shishu Bikash Kendro (Child Development Centre) of Dhaka Shishu (Children) Hospital, causing developmental delay and neurological impairments. Lead concentrations measured around 80 micrograms/dl to 180 micrograms/dl in the tested children's blood, which is 7-16 times more than the acceptable limit (Khan, 2000). The safe concentration advocated by the U.S. Center for Disease Control and Prevention is 10 micrograms/dl (1999). Researchers also identified a significant rise in mean blood lead levels in people living in urban slums, compared to those living in urban middle-income or rural areas.

Until these recent studies conducted by the Dhaka Children's Hospital and Bangladesh Atomic Energy Commission found high levels of lead in the blood samples of children in Dhaka, the air problems in the country were not addressed with much importance.

In addition, it has been found that Dhaka city has volatile organic compounds beyond tolerable limits, some of which cause cancer. Emissions from two stroke auto-rickshaws in Dhaka were found to contain 4 to 7 times the maximum permissible level of VOC. (M. Alauddin, August 1998).

3.3.4.2 Impacts on Livestock

An interest in the effects of air pollution on animals has generally developed as a corollary to concern about human health. Livestock get poisoned through a two-step process; firstly there is an accumulation of airborne contaminants in the vegetation and fodder, followed by subsequent poisoning of the animals when they eat this contaminated vegetation and fodder.

3.3.4.3 Impacts on Vegetation

Air pollution has long been known to have an adverse effect on plants. A number of air pollutants affect plants, but the commonly encountered ones are sulfur dioxide, nitrogen oxides, and ammonia. Absorption of pollutant gases by plants depends primarily on light intensity, humidity, moisture supply to roots, and temperature. Therefore, knowing pollutant concentrations, and trans-boundary migration of pollutants alone is not enough for assessing the impacts. Moreover, mitigation requires an integrated approach that considers seasonal variability of the weather.

3.3.4.4 Impacts on Ecosystem

There is also a direct impact from air pollution on aquatic ecosystems through acid rain. Transportation of air pollutants occurs not only through wind movement, but also by water flow. Therefore, an integrated regional level assessment is required.

3.3.5 RESPONSES BY DIFFERENT AGENCIES

3.3.5.1 Policies, Roles and Regulatory Responses

Every country needs a practical and dynamic set of rules and regulations to prevent and mitigate environmental pollution. The environmental laws existing in Bangladesh may be categorized on the basis of broad objectives as follows:

- Protection of environmental health
- Control of environmental pollution
- Conservation of natural and cultural resources.

The first regulation related to environment in Bangladesh was the Factory Act of 1965, through which workers' health-related issues were addressed. This was followed by the earliest recorded environmental protection act, known as the "Water Pollution Control Ordinance, 1970". However, none of these ordinances addressed air pollution problems. This major oversight may have been due to the almost negligible air pollution

problems at that time. In view of growing environmental pollution this ordinance was repealed, and the Environmental Pollution Control Ordinance (EPC), 1977, was promulgated. This ordinance provided for the control, prevention, and abatement of pollution of the environment in Bangladesh. It dealt with pollution of air, surface and ground waters, and soil by discharge of liquid, gaseous, solid, radioactive, or other substances. Although the order passed under the EPC 1977, was legally in place, implementation of environmental laws never took place.

The environmental scenario in Bangladesh changed considerably following rapid industrialization. The Ministry of Environment and Forest, and the Department of Environment were created in 1989. As a signatory to Agenda 21, Bangladesh is committed to implement this international legal instrument through national programs and policies. The Environment Policy of 1992 was an important development in this regard. Further, the Environmental Conservation Act, 1995, and the Environment Conservation Rules, 1997, were approved by the Bangladesh National Assembly to restrict and mitigate ever-growing environmental problems in the country.

Therefore, the Bangladesh National Environmental Policy 1992, Environmental Conservation Act 1995, and the Environmental Conservation Rules (ECR) 1997, now contain relevant policies, such as authority to inspect and regulate facilities, collect samples, impose civil penalties, adopt rules, and implement environmental clearances (see Table 3.3.10). Under the Rules of 1997, the following standards have been set.

- Ambient Air Quality Standards
- Vehicular Exhaust Emission Standards
- River Transport (Mechanized) Emission Standards
- Standards for Gaseous Emission for Industries or Projects

3.3.5.2 Recent Government Decisions

Recently the Ministry of Energy and Mineral Resources (MEMR) has taken important decisions in this connection, as follows:

(i) The minimum standard of lubricating oil for two-stroke engine should be APITC or JASOFB.

(ii) Marketing of straight mineral oil should stop immediately. If anyone sells straight mineral oil,

Table 3.3.10 Policy Responses to Air Pollution through Acts, Rules, and Laws in Bangladesh

Act/Rule/Law	Control/Prevention Response
A. The Brick Burning (Control) Act, 1989 (Act number 8 of 1989) B. **The Brick Burning (Control) Amendment Act, 1992**	• Control of brick-burning • **Required a license from the appropriate authority** • **Restricts brick-burning with fuel wood**
C. Bangladesh Environmental Conservation Act, 1995 (ECA 1995)	• Declaration of ecologically critical areas • Regulation with respect to vehicles emitting smoke harmful for the environment • Environmental clearance • Regulations of the industries and other development activities-discharge permit • Promulgation of standards for quality of air, water, noise, and soils for different areas and for different purposes • Promulgation of acceptable limits for discharging and emitting waste
D. Environment Conservation Rules, 1997 (ECR, 1997)	• The National Environmental Quality standards for ambient air, various types of water, industrial effluent, emission, noise, vehicular exhaust, etc • Requirement for the procedures to obtain environment clearance • Requirement for IEE/EIA according to categories of industrial and other development inventories
E. Environment Court Law, 2000	Government has given highest priority to environment pollution and passed 'Environment Court Act 2000' for completing environment related legal proceedings effectively

he should be penalized. Bangladesh Petroleum Corporation (BPC) will circulate this information in the newspaper, and ensure implementation properly. A monitoring cell should be constituted by BPC.

(iii) BPC will mention the minimum standard of lubricating oil determined by the Government when signing agreements with private companies.

(iv) To protect the environment appropriate regulations are to be enacted on disposal of used lubricants.

(v) All blending plants (including private) should be of international standard, and must be upgraded with laboratory facilities.

(vi) Marketing of products in small packs is to be encouraged, and a committee is to be constituted to determine the packing standard.

(vii) A well-equipped and effective laboratory is to be established for testing lubricants and fuel oils.

3.3.5.3 Other Possible Policy Initiatives

1) Promulgation of new laws and modification of old laws to strengthen controlling authority.

2) Banning import of two-stroke engines.

3) Phase-wise plan to take two-stroke engine vehicles off the roads.

4) Imposing extensive penalties on polluters and industries.

5) Motivating the public through promotional activities to use less polluting vehicles.

6) Increasing the number of public vehicles (such as buses, double-deckers, etc.) to reduce the number of vehicles on the streets.

7) Remove traffic congestion by reducing the member of non-motorized vehicles, and by restricting the movement of such vehicles within a certain part of the city, and during a specific period of the day.

8) 8) Improving the mass-transport system within the urban areas, and increasing parking facility.

9) Regular monitoring of the ambient air quality and vehicular emissions.

10 Public awareness campaigns.

11) Proper implementation of present laws.

12) Promulgate standards for ground level ozone concentration within the ECA 95 and ECR 97.

13) Ensure through promulgating law that are existing and imported vehicles be fitted with catalytic converters.

3.3.5.4 Program Responses

A. Fuel switching

In 1985-86 the Bangladesh Petroleum Corporation started a project to use Compressed Natural Gas (CNG) in vehicles instead of gasoline. The primary objective was to reduce vehicular emissions, as combustion of CNG produces less pollution than gasoline. The World Bank donated Taka 225 million to initiate the project.

Data on the number of vehicles converted to CNG-driven ones over the last nine years are shown in Table 3.3.11. It indicates that a negligible number of cars have been converted for CNG. This is due to lack of promotional activity, reluctance of people to embrace a new technology, unavailability of filling stations, maintenance, etc. However, its use may increase with the appropriate push from the Government and by increasing the promotional campaign, which will eventually reduce vehicular emissions. On the other hand, private sector participation in using CNG, particularly for taxicabs, has started and the numbers are significant.

Table 3.3.11 Number of Vehicles Converted to CNG

Year	No. of Vehicles Converted
1985-86	2
1988-89	19
1989-90	9
1990-91	6
1991-92	10
1992-93	16
1993-94	3
1995-96	13
1996-97	86

Source: National Action Plan of Air Pollution, 1999

B. Control Options Applied and Abatement efficiency

In order to control and limit vehicular exhaust especially in the urban area, several initiatives has been undertaken by the GoB which is described in Table 3.3.12.

Table 3.3.12 Control Options Applied and Abatement Efficiency

Source	Control option applied	Abatement efficiency
Vehicular air pollution (mainly urban-based)	Phase out of leaded gasoline in July 1999, import of unleaded gasoline is implemented Banning new licenses and road permits for two-stroke engine three-wheelers (baby-taxis) in Dhaka City is implemented in the first phase Introduction of low Sulfur content fuels Introducing 2T lubricants mandated from 1 January 2001 but not implemented Building infrastructure and incentives to promote CNG as a vehicular fuel	Decision taken by the Government and implementation process is under way. Sulfur ..... to 0.5 per cent from 1 per cent. 51 filling stations to be installed in 10 years.

C. Air Quality Management Project (AQMP)

The DoE has undertaken a project on Air Quality Management, which is being funded by the World Bank. The project has the following two components:

Component-1: Enforcement, Standards, and Pilot Control Programs

This component that is essential for long-term success of emissions reduction measures will include; (i) enforcement of emissions regulations for in-use vehicles; (ii) development of fuel standards (petrol and lubrication oil), and vehicle emission standards; and (iii) pilot studies for vehicular pollution control.

Component-2: Air Quality Monitoring and Evaluation

This component will generate essential air quality information, and evaluate pilot activities listed in Component-1. It will include, (i) air quality monitoring in Dhaka; (ii) awareness raising campaigns; and (iii) air quality management assessment for strategy formulation.

3.3.6 OPTIONS FOR AIR POLLUTION MANAGEMENT

There are a few low cost measures that could make a substantial dent in the emissions from vehicles with two-stroke engines, which are the major causes of air pollution in Bangladesh, especially Dhaka city. Among these the following are probably the most significant, and discussed in more detail.

- Use of low smoke 2T lube oil for two-stroke engines
- Inspection and maintenance
- Traffic management

Use of low smoke lube oil for two stroke engines

Specially formulated lubricants for two-stroke engines (JASO-FB/FC) with low smoke are now available from major oil companies. These are usually referred to as '2T' oils or lubes. It is known that these better-quality lubricating oils can decrease emissions by half. Recently GoB has mandated the use of 2T lubricants in two stroke engine vehicles from 1 January 2001 but it is yet to be implemented due to supply problem.

Inspection and maintenance

It is known that emission from engines can be reduced substantially through proper inspection and maintenance. For example the effectiveness of this measure in the case of two-stroke engines would be a reduction of up to 35 per cent in emissions. The increase in maintenance cost would be offset by the better engine performance, and resulting reduction of fuel cost. The benefits would include reduced health maintenance costs, and lower mortality.

Traffic management

Traffic management refers primarily to measures that address traffic congestion. Successful traffic management reduces congestion and thus emission by diminishing idling vehicles, the need for acceleration

and deceleration, and fuel consumption. The major components required are:

- Traffic signals
- Introduction of one-way roads
- Improving parking facilities
- Coordination of different vehicular modes
- Separate lanes for different speed traffic

Special Option for Dhaka

The presence of very low speed non-motorized vehicles (mainly rickshaws) with a maximum speed of 10 km/hour, and their interaction with motorized traffic presents a very special traffic problem. Rickshaws cannot be removed due to socio-economic constraints. Hence, creative measures are needed to limit the impact of non-motorized traffic. Some of these have already been tried sporadically, on a limited scale, but what is needed is a long-term commitment, and substantially scaled-up operations.

A suggested measure for Dhaka city is that non-motorized traffic is restricted from arterial roads, with some exceptions for the circulation of such traffic. The exceptions would consist of non-interactive special lanes and crossings, to maintain non-motorized flow between different regions. Some expected effects from this measure that will reduce pollution would be that traffic flow-speed will increase, and fuel consumption will be reduced for the same vehicle-miles traveled.

3.3.7 CONCLUSION & RECOMMENDATIONS

The ultimate success of any decision is the extent to which it translates into action. It is apparent from the discussion above that it is possible to reduce emissions from vehicles with two-stroke engines by about two thirds through the use of low smoke lubricants, and proper inspection and maintenance.

Some additional decisions and actions to reduce air pollution caused by two-stroke engine baby-taxis are needed to really improve the air quality. Some of these are given below.

- GoB decision on mandatory use of 2T lubricant should be strictly enforced
- Introduction of sachet packs of 2T lubricant of JASOFB standard should be done as soon as possible, as these can be afforded by the drivers.
- A suitable set of standards of emission for the two-stroke engine baby-taxis and other vehicles to be promulgated, as current standards are not appropriate. DoE can promulgate such standards.
- Effective enforcement of vehicle compliance to these standards has to be ensured. This could be a multi-agency enterprise. For example, through the vehicle registration process the Bangladesh Road Transport Authority could ensure compliance at the time of registration. DoE can do spot checks of vehicular emissions under the Environmental Protection Act.
- These checks must be done using reliable equipment with printed outputs, so that transparency is ensured, because otherwise public support for the checks cannot be maintained.
- Enforcement program inspectors should be adequately trained.
- If sufficient manpower or equipment is not available at Government agencies for enforcement work, some type of distributed system should be developed through the private sector.
- Provision for repair at reasonable cost has to be ensured for vehicles that fail enforcement test procedures. For this adequate attention to repair procedures, and mechanic training has to be given.
- Periodic evaluation and review of all the actions and issues should be done to identify problems and find their solutions.

References

Alauddin, M. (1999) *Leaded Vs Unleaded Gasoline : Some Technical Issues*, The daily Star, Dhaka, Bangladesh.

BBS (1997a) *Bangladesh Compendium of Environmental Statistics*, Bangladesh Bureau of Statistics, Dhaka Bangladesh.

BBS (1997b) *Statistical Yearbook of Bangladesh*, Bangladesh Bureau of Statistics, Ministry of Planning, Dhaka, Bangladesh.

Chowdhury, K.I. (1999) *State of Environment Report, Bangladesh, 1999*, Forum of Environmental Journalist of Bangladesh (FEJB), Dhaka, Bangladesh.

DoE (1999) *National Action Plan for Bangladesh on Control and Prevention of Air Pollution and its Likely Transboundary Effects*, Baseline Studies, Department of Environment and Ministry of Environment and Forest.

DoE (2000) Personal Communication

Gain P. (1998) *Bangladesh Environment: Facing the 21st Century*, Society for Environment and Human Development, Dhaka.

Hussain, A. (1998) *Analyzing Air Samples Collected from the Shewrapara Area of the City*, George Mason University, Virginia, USA.

Khaliquzzaman, M., Biswas, S.K., Tarafder, SA and Islam, A. (1999) *Nature and extent of airborne particulate matter pollution in urban and rural areas of Bangladesh during 1993-1998.* Bangladesh Atomic Energy Commission, December 1999.

Khaliquzzaman, M. (2000) *Introduction to low smoke lubricants for baby taxis and other vehicles with two stroke engine in Dhaka: Prospects and Problems*, Consultant, The World Bank, Dhaka, Bangladesh.

Khan, N.Z. (2000) *Destroying Our Childrens Brains with Lead Pollution*, Narigrantha Prabartana, Dhaka, Bangladesh.

NIPSOM (2000) Personal Communication

Shah Jitendra, J., Tanvi, N. and Brandon Carter J. (ed) *Urban Air Quality Management Strategy in Asia: Guidebook*, The World Bank, Washington D. C. 1999.

Wahid, A., Maggs, R., Shamsi, S.R.A., Bell, J.N.B. & Ashmore, M.R. (1994) *Air Pollution and its Impacts on Wheat Yield in the Pakistan Punjub*, Department of Botany, University of Punjab, Quad-e-Azam Campus Lahore, Department of Biology Imperial College at Silkwood Park Berkshire. UK.

3.4.1 INTRODUCTION

"Biological Diversity" means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; it includes diversity within species between species, and of ecosystems (Article II, CBD, 1992). Literal meaning of biodiversity is the diversity of all life forms on earth. This includes the various races and species of all microbes, plants, and animals that live on earth, including their genetic differences, i.e., the gene pool of each species.

Bangladesh is a transitional zone of flora and fauna, because of its geographical settings and climatic characteristics. As mentioned in the overview section of the report that there are many rivers and streams existing in the country covering a length of 22,155 km. In addition to the regular inland waters, seasonally a large part of the country remains submerged for 3-4 months during monsoon.

This country is rich in fish and aquatic resources, and other biodiversity (Table 3.4.1). Bangladesh's inland water bodies are known to be the habitat of 266 species of indigenous fish, 13 exotic fish, 56 prawns, about 26 freshwater molluscs, and 150 birds.

Table 3.4.1 Flora and Fauna Recorded in Bangladesh

Category	Total Number of Species
Flora	
Angiosperms	5000
Gymnosperms	5
Algae/seaweed	168
Fauna	
Sponges	3
Corals	66
(Marine + freshwater) Molluscs	(336+26) 362
Insects	2493
Mites	19
Shrimp/prawns	56
(Marine + freshwater) Crabs	(11+4) 15
Lobsters	3
Echinoderms	4
(Marine + freshwater) Fish	(442+266) 708
Amphibians	22
(Marine + inland) Reptiles	(17+109) 126
Birds	628
(Marine + inland) Mammals	(3+110) 113

Source: Khan, 1991; Ahmed and Ali, 1996; Alam 1967; IUCN, 2000

The marine water bodies (200 nautical miles along the coast) are also remarkable for being habitat of 442 species of fish. There are at least 36 species of marine shrimps. About 336 species of molluscs, covering 151 genera have been identified from the Bay of Bengal. In addition, several species of crabs, and 31 species of turtles and tortoises, of which 24 live in freshwater, are found in Bangladesh (Sarker and Sarker, 1988; and Ali, 1997). Ahmed and Ali (1996) published a species list of 168 seaweeds, 3 sponges, 15 crabs, 3 lobsters, 10 frogs, 3 crocodiles, 24 snakes, 3 otters, 1 porcupine, 9 dolphins, and 3 species of whale found in Bangladesh (Table 3.4.1).

There are numerous invertebrates in the country that are yet to be identified. Various authors have recorded about 70 species of bees, and many species of wasps (Alam, 1967).

In Bangladesh only about 8-10 per cent of the land area is under good canopy cover. It supports approximately 5000 species of angiosperms, out of which about 300 species are being cultivated. The list of medicinal plants is currently being revised at the Bangladesh National Herbarium (BNH), and is expected to exceed 5000 species. Mia and Haque (1986) showed there are 224 species of timber-yielding plants found in Bangladesh. Khan and Mia (1984) described 130 species of indigenous fiber plants.

The IUCN Bangladesh Red Data Book (2000) has described 266 species of inland fishes, 442 marine fishes, 22 amphibians, 109 inland reptiles, 17 marine reptiles, 388 resident birds, 240 migratory birds, 110 inland mammals, as well as 3 species of marine mammals in Bangladesh.

According to the Red List of IUCN, there are 54 species of inland fishes, 8 amphibians, 58 reptiles, 41 resident birds, and 40 mammals, which are threatened throughout the country. Among the marine and migratory species of animals, 4 fishes, 5 reptiles, 6 birds, and 3 mammals are threatened. So far, the Red Data Book on plants, which is under preparation at BNH, lists 96 seed-bearing plant species that are threatened.

The depletion of biodiversity is the result of various kinds of human development interventions and activities, especially in the areas of agriculture, forestry, fisheries, urbanization, industries, chemicals, minerals, transport, tourism, and energy (Table 3.4.2).

3.4.2 PRESSURES ON BIOTA

Both flora and fauna are threatened by the loss of habitat resulting from increasing human populations, and unwise bio-resource utilization (Table 3.4.2). Increasing demand for timber and fuel-wood, encroachment for other purposes, and *Jhum* (shifting) cultivation in the hilly districts, might be the aggravating factors in the annual rate of deforestation and degradation. The unplanned rapid urbanization and industrialization are leading to waste and pollution problems that affect natural ecosystems. As the land and water-based ecosystems are environmentally compromised, the flora and fauna populations are being seriously affected.

This biodiversity section described mostly on destruction of habitat, overexploitation of flora and fauna, and illegal trades. Other issues such as water pollution section of the report deals with industrial pollution and oil spillage, and land degradation section deals with agrochemicals, encroachment in the natural forest and changes of land use pattern.

Table 3.4.2 Major Threats to Biodiversity

- Destruction of habitat
- Overexploitation of flora and fauna
- Indiscriminate use of agro-chemicals
- Industrial waste disposal.
- Oil spills
- Encroachment into the natural forests
- Change in land use pattern and land use conflict

Several wildlife species have become extinct in Bangladesh, and many more are threatened. Most of the economically important local plants, medicinal plants, etc., are also under equally great pressure, and are likely to be lost due to habitat destruction, and unsustainable harvesting.

3.4.2.1 Habitat Depletion and Over Exploitation

Fish

The people of Bangladesh largely depend on fish to meet their protein needs, especially the poor in rural areas. Several decades ago there was an abundance of fish in this country. But recently, capture fish production has declined to about 50 per cent, with a negative trend of 1.24 per cent per year (Ahmed, 1995b). Despite the constant depletion of the river, canal, and flood plain habitats for years, Bangladesh still holds the world's most diverse and abundant

A view of mono culture, destroying habitat

inland fisheries. But the availability of many species that were very popular locally has been drastically decreased, and some are no longer found in the country. On the migration journey to the floodplains, and the return to safe sanctuaries, populations of fish now face many obstacles and hazards, which seriously disturb reproduction in the open water and ponds.

The physical loss, shrinkage, and modification of aquatic habitats for fish, prawn, turtle and other aquatic organisms are said to be the major factors involved in depleting fish varieties. Such loss or shrinkage of aquatic habitats has been the result of thousands of physical structures, dikes, and drainage systems that have been constructed in Bangladesh in an effort to control floods, cyclones, and other natural calamities. These structures have disrupted the natural flow of waters in closed rivers, diverted rivers, and have dried up water bodies. Such physical constructions have also changed or damaged the local ecosystems and hydrological features, resulting in irreparable damages to fisheries resources. Studies done under the Flood Action Plan (FAP) declared that all Flood Control Drainage (FCD) and Flood Control Drainage and Irrigation (FCDI) projects contributed to the decline of fish stocks and fisheries by creating obstacles in the fish migration routes. As a consequence, fish production have declined. Land reclamation required for the implementation of these projects has also reduced the permanent water bodies.

The extensive irrigation schemes for agricultural fields, and indiscriminate use of agrochemicals are changing the feeding and breeding grounds of

many indigenous fish species. Discharge of pollutants into water bodies (rivers, canals, ponds, etc.) from industries, and over-fishing (especially of juvenile and brood fishes) are highly responsible for the destruction of fish species throughout the country. Short term leasing of *haors* and *baors* to individuals for commercial exploitation has led to many species becoming locally extinct. This can be attributed to the practice of almost total intake of fish stocks by dewatering the water bodies while harvesting fish. Moreover, there has been a reduction of sanctuaries for natural replenishment of fish species throughout the country, which is another factor leading to shrinkage and destruction of aquatic habitats.

Amphibians
In Bangladesh, 22 species of Amphibians have been recorded (Table 3.4.1). Some of these are economically important and thus are being exploited commercially. Until the early eighties many traders in the country were exporting frog legs in large quantities. Most of the frogs were collected from the wild, and exported as a frozen food item. This practice also causes insect and predator populations to be affected.

Reptiles
The depletion of reptilian fauna in the country is noteworthy. Reptiles are environment friendly as they eat many agricultural pests, and help control their numbers. However, turtles, tortoises, snakes, lizards, and crocodiles are exploited economically because of a tradition of making useful commodities from their body parts, e.g., bones, skins, etc. Therefore, most of them are in high demand by traders in these items, and are over-exploited.

Birds
The conversion of wetlands into agricultural lands, large-scale deforestation, and human overpopulation are considered to be the major factors causing many species of birds in Bangladesh to be threatened. There is an illegal trade in birds that is prevalent.

Mammals and Other Wildlife
The mammalian fauna of Bangladesh is the most highly affected from their habitat destruction and over exploitation. Very exceptionally people in Bangladesh use some wildlife species. Most of them are used either as food (e.g. birds, deers, wild boars, etc.), or as commodity (e.g. medicine, handicrafts, etc.), or as pet (e.g. turtles, lizards, snakes, parakeets and hill Mayna, etc.). However, the country is yet to formulate appropriate policies and guidelines to manage the utilization of these biological resources in a sustainable manner. Most of them are exploited in an unsustainable way, and hence, a number of wildlife species have become threatened.

Flora
Natural forests throughout the country are increasingly being depleted. Various types of development activity, such as dikes, highway, road construction, and other infrastructure development have further intensified deforestation, and destruction of natural forests in Bangladesh. Briefly, the other causes of deforestation are listed below. The degradation of forestland is described in detail in the Land Degradation section of this report.

- Shifting cultivation (*Jhum*), and inappropriate utilization of forest resources.
- Overgrazing, illegal felling, and fuel wood collection.
- Uncontrolled and wasteful commercial exploitation of forest resources.
- Monoculture and commercial plantation.
- High population pressure on forestlands.
- Conversion of forests and wetlands for agricultural use.
- Poverty and unemployment in the rural areas.
- Encroachment into forestland.

3.4.3 STATE AND IMPACTS

Unfortunately, the degradation and loss of natural resources in Bangladesh started a long time ago, and now they are all equally depleted, including biodiversity. Various land use and water policies have had significant impacts on natural ecosystems and have changed their character and ability to support biological resources.

The list of extinct animals of Bangladesh has been prepared based on earlier published information regarding fauna (Pocock, 1939; Mountfort, 1969; Prater, 1971; Husain, 1974; Hendrichs, 1975; Green, 1978; Khan, 1982a, 1985). According to further field studies and the compiled Red List of IUCN (2000), 64 species of vertebrates have been recorded as critically endangered, 86 as endangered, and 51 as vulnerable species. The Bangladesh National Herbarium is preparing a similar type of list for flora.

3.4.3.1 Fauna

Aquatic invertebrates
In Bangladesh there are about 362 species of molluscs, of which 336 are marine and 26 are freshwater (Table 3.4.1). Low-lying marshlands are the best habitat for them.

Shrimp
Bangladesh earns quite a good amount of foreign exchange from the export of shrimp and prawn. Shrimp export brings in the most attractive financial returns. In 1981-82, Bangladesh exported 6,903 metric tons of shrimp, worth Tk. 904 million. This rose to 18,665 metric tons amounting 4,373 million in 1987-88. Another report estimates exports of 4,386 metric tons in 1983-84, which reached 23,530 metric tons in 1992-93. Recently the amount is estimated to be about 38,000 metric tons, and it is increasing every year. Most of this comes from shrimp culture in *gher* or through excavation of ponds that are seeded with fry, which are later harvested. About 10,000 metric tons of the shrimp exported comes from coastal wild shrimp collection.

As a consequence of the shrimp trade, a vast area in the coastal zones of Khulna, Satkhira, Bagherhat and Cox's Bazar has been converted into shrimp farm. Bangladesh has about 2.5 million hectares of brackish water, of which 0.13 million hectares is under shrimp culture (Ahmed, 1995a). Two cultured species are *Penaeus monodon* (brackish-water prawn) and *Macrobrachium rosenbergii* (freshwater prawn), which are mainly cultured in ponds, beels, and paddy fields.

The large landowners, and city based non locals mainly dominate shrimp culture in the southern districts. This has created serious socio-economic problems in those areas, besides ecological issues. Other natural resources and biodiversity are seriously affected or neglected by the change in environmental conditions in the area, especially cattle, poultry and goats. A big threat to other aquatic biodiversity is caused by the indiscriminate destruction of various other types of fish and shrimp fry that get captured when local people capture wild shrimp fry along the coastal tidal areas.

Crab
Unlike shrimp, crabs are not cultivated but rather collected from wild sources and exported to foreign countries. This is big business in the coastal areas, and thousands of fishers are involved in it. As mentioned earlier, there are about 7 species of crab found in the Sundarbans, and about 15 throughout the whole country (Table 3.4.1). The Mud Crab (*Scylla serrata*) is the most commercially important species, and is widely distributed in the Indo-Pacific region, including the Bay of Bengal.

Bangladesh started commercial export of crabs from 1987 and in 1990 to 91 earned foreign exchange of Tk. 2.7 million. Since then, the harvesting and export of crabs has increased to a high level. During the last fiscal year (1999-2000) Bangladesh earned about Tk. 30 million from crab export. The main countries importing crabs from Bangladesh are Singapore, Hongkong, China, Taiwan, and Malaysia. The major sources of this exportable item are from crab fishing in and around Sundarbans, Chakaria Sundarbans, coastal shrimp culture farms, and some fattening ponds in Satkhira, Bagherhat, Pikegacha, and Mongla area. Now about 500,000 people are engaged in the fishing, fattening and trading of crabs, as well as in export.

Fish
Fish is the main dietary source of protein in Bangladesh, and fisheries product supplying over 85 per cent of the total animal protein intake.

The fish and fisheries sector in Bangladesh is keeping very important role in national economy. The principal sources are inland fisheries and artisan marine fisheries. This sector contributes 4.7 per cent of GDP, 6.9 per cent of agricultural GDP, and 11 per cent of export earnings (Ahmed and Ali, 1996). Over 2 million people are involved in this sector as fishermen, traders, transporters, packers, etc.

In 1940-50s about 95 per cent of animal protein came from fish in the daily diet of the people of the country, which was 80 per cent before 1980. At present fish provides 71 per cent of the daily per capita animal protein intake. Rivers and wetlands attribute plenty of opportunities for fish culture as well as hold natural habitat for fishes. The fisheries resources of Bangladesh are among the richest in the world, and the inland fisheries production ranks 3rd, where China and India are leading the global position.

The total inland capture is still contributing the major part of the total fish production in the country, which is about 52.2 per cent. The total annual production of the inland culture fishes is

about 23.3 per cent, where as the production of marine fishes is about 24.5 per cent (Ahmed & Ali, 1996). The fish species that are frequently caught in the Bay of Bengal are *Arius* spp, *Johnnius belangerii*, *Upensus sulphurus*, *Harpodon nehereus*, *Pompus argenteus*, *Metapenaeus monoceros*, *Penaeus monodon*, *Penaeus indicus*, etc.

According to the studies conducted by the Department of Fisheries of Bangladesh, a remarkable declining trends are already discernible in the capture fisheries of Bangladesh. A host of man induced stresses due to large scale water abstraction for irrigation, construction of embankments for flood control, siltation, and soil erosion due to deforestation in the catchment water, pollution from industrial, agriculture and municipal waste, etc. have left a trial of devastating effects on fish stocks of the country. The world harvest of fish crustaceans and mollusc reached a record of 99.6 million metric tons in 1989 then decline to 95.2 million metric tons in 1990 (Ahmed, 1999).

IUCN Red List (2000) revealed 54 threatened species of fishes in Bangladesh, some of them are - Grey feather back (*Notopterus notopterus*), Freshwater eel (*Anguilla bengalensis*), Snakeheads (*Channa marulius*, *C. barca* and *C. orientalis*), Darkina (*Rasbora rasbora*), Bhagna (*Labeo boga*), Olive barb (*Puntius sarana*), Mahashol (*Tor tor*), Baghair (*Bagarius bagarius*), Bacha (*Eutropichthys vacha*), Tara baim (*Macrognathus aculeatus*), Neptani (*Ctenopis noblis*), Napitkoi (*Badis badis*), and Bhangan (*Liza tade*). No such endangered or threatened list of marine fish is not available in Bangladesh (Ahmed, 1995).

In the fisheries sector shrimp cultivation has become a major concern for the past decade. Shrimp cultivation has caused a serious environmental damage where fishes and other aquatic biodiversity also harmed most highly.

Frogs

Frogs are in high demand for the international market, although they are environmentally important because they eat a lot of insects (about 42 species) that are agricultural pests. Therefore, indiscriminate collection of frogs from agriculture fields has resulted in enormous use of insecticides to control the subsequent colossal attack of insect pests. The excessive harvesting of frogs from the wild has also affected the food chain of their predators, such as monitor lizards, snakes, and many species of birds. Recently, the Bangladesh government has enacted some regulations to control the trade in frog's legs by imposing a ban on the export of frogs.

Table 3.4.3 List of Marine Turtles

Sl. No.	English name	Scientific name
1.	Olive Ridley	*Lepidochelys olivacea*
2.	Green turtle	*Chelonia mydas*
3.	Hawksbill	*Eretmochelys imbricata*
4.	Loggerhead	*Caretta caretta*
5.	Leatherback	*Dermochelys coriacea*

Source: CNRS, 1999

Turtles and Tortoises

About 12 species of reptile are critically endangered, including the estuarine crocodile, Gangetic gharial, river terrapin, tortoise, turtle, flying lizard, and reticulated python.

Bangladesh supports 25 species under Order Chelonia, of which 18 are freshwater turtles, 5 are marine turtles (Table 3.4.3), and two are land tortoises. The Bostami turtle (*Aspiderates nigricans*), found only in the pond of Saint Bayezid Bostami in Chittagong (hence its name), is the only endemic wildlife of Bangladesh. The majority of freshwater turtles are herbivorous, and thus control growth of aquatic weeds and other submerged vegetation to maintain a healthy aquatic environment for other wildlife and fish.

Besides their natural ecological role, the turtle and tortoise populations in Bangladesh provide a little animal protein to a small percentage of people, especially ethnic communities. The soft shelled turtles have been one of the major non-traditional export earners for the country for a long time. All the species exported are collected from nature. The collection of turtles' eggs from the seashores of Cox's Bazar, St. Martins, and Teknaf is a major threat to the sea turtles.

Monitor Lizards

The monitor lizards play a very vital role in agricultural pest control. However, their skins are in high demand to make a variety of fancy leather items. There are three species of monitor lizards found in Bangladesh viz. *Varanus bengalensis*, *V. salvator*, and *V. flavescens*. All these have been commercially exploited during the last half-century, with no consideration of maintaining their populations, or the ecological consequences. The population of monitor

Table 3.4.4 List of Extinct Wildlife in Bangladesh

Animals	Common name	Scientific name
Reptiles	Marsh Crocodile	*Crocodylus palustris*
Birds	Pink-headed Duck	*Rhodonessa caryophyllacea*
Birds	Common Peafowl	*Pavo cristatus*
Mammals	One-horned Rhinoceros	*Rhinocerus unicornis*
Mammals	Asiatic Two-horned Rhinoceros	*Didermoceros sumatrensis*
Mammals	Java Rhinoceros	*Rhinocerus sondaicus*
Mammals	Wolf	*Canis lupus*
Mammals	Swamp Deer	*Cervus duvauceli*
Mammals	Hog Deer	*Axis porcinus*
Mammals	Gaur	*Bos gaurus*
Mammals	Banteng	*Bos banteng*
Mammals	Wild Buffalo	*Bubalus bubalis*
Mammals	Blue Bull (Nilgai)	*Bosephalus tragocamelus*

Source: IUCN, 2000

lizards has now fallen to a vulnerable status, because of their habitat destruction and indiscriminate capture for skin.

Birds

The population of birds in Bangladesh is still very rich, and there is a wide variety in the country (Table 3.4.1). However, bird populations around the globe are declining at an alarming rate, and that does not exclude Bangladesh. IUCN's Red List (2000) revealed that among 388 species of resident birds, 41 species are threatened in this country. The primary threats to them are habitat destruction, illegal trade, and over-hunting.

There are 19 species of birds that have been recorded as critically endangered. Some of these are: Black francolin, peacock, White-winged duck, Comb duck, Hornbill, Pin-tailed green pigeon, and Red-headed vulture. About 2 species of birds have become extinct in Bangladesh (Table 3.4.4).

Mammals

About 10 species of mammals have become extinct in Bangladesh (Table 3.4.4), and 40 species are threatened (IUCN, 2000).

There are 21 critically endangered species of mammals enlisted by IUCN. Some of these are: Slow loris, Crab-eating macaque, Hanuman langur monkey, Hoolock gibbon, Asiatic wild dog, Golden Cat, leopard, tiger, otter, bear, dolphin, Asiatic elephant, sambar, and anteater.

Among the wild animals, mammals have been highly depleted over the last few decades in Bangladesh. The most affected ones are leopard, Royal Bengal Tiger, spotted deer, Gaur, elephant, fox, monkey, jackal, porcupine, hedgehog, and anteater. Their populations are so depleted that in recent times they are rarely found.

There are still various types of mammals found in the forests. Wild elephants are found in the Chittagong Hill Tracts (CHT). At one time, wild buffaloes, sambars, barking deer, leopards, and many other animals were spread all over the CHT, but now most of them are rarely seen.

Due to degradation of the natural forest, most of the wildlife in the Sal forest has also rapidly vanished. Leopards, bears, deer, and many other animals, which were abundant in the Sal forest areas, have now totally disappeared. Bands of monkeys are rarely seen these days. Although common in the past, pheasants, peacocks, pythons, and a variety of birds have no place now in the afforested rubber and fuel-wood plantations.

3.4.3.2 Flora

Bangladesh supports approximately 5000 floral species, of which about 300 species are being actively cultivated. The list of threatened vascular plant species is being prepared by BNH, and will be published soon. They are also preparing a list of medicinal plants, and the number so far exceeds 500 species. A detailed account of 200 plants known to be effective in diarrheal diseases has been prepared.

Bangladesh is primarily a land of agriculture, and rich in germplasm resources of some of the world's most important crops, namely banana, eggplant (aubergine), cotton, bean, jute, lime, litchi, mango, rice, sugarcane, tea, taro, etc. The predominant crop is rice, which covers up to 80 per cent of the land area. The number of indigenous rice cultivars is estimated to be 8,000. There are two wild relatives of rice found, namely, *Oryza rufipogon* and *Porteresia coarctata*. Various research institutes in the country have collected germplasm of about 5000 cultivars of rice, 3685 jute, 256 tea, 1098 timber, 11 bamboo, 18 wild grasses, and 2929 varieties of miscellaneous crops.

Threatened Plants

A tentative list of about 26 angiosperm species endangered in Bangladesh was prepared by Khan (1991a) as the first step in intensive field studies to

locate the species in the wild, and collect relevant data. This is being followed up by screening, preparing status reports, reviewing information, and analysis of the data to assign the species to the IUCN Red List categories (IUCN, 1994). It is still premature to categorically name the endangered plants of Bangladesh until the field surveys are completed. But the current project for a Red Data Book of Bangladesh Plants taken up by BNH is nearing completion. The list of threatened plants has been expanded to more than 100 in number.

Medicinal Plant Resources

Yusuf *et. al.*, (1994) in a recent publication gave a list of 546 medicinal plants that occur in Bangladesh. However, the inventory is not complete, and many plants with medicinal value are yet to be discovered. The Rangamati Hill District in CHT still harbors a portion of virgin forest. But the procurement of medicinal plants from the wild habitat for professional collectors to make local medicines is unscientific, indiscriminate, and in most cases leads to overexploitation. There is severe depletion of the natural stands, without any provision for the regeneration of species. Some rare species like Ulat chandol (*Gloriosa superba*), Sarpo gandha (*Rawolfia serpentina*), and Aswa gandha (*Withania somnifera*) have become regionally endangered.

The Government of Bangladesh is conscious about the need to take corrective action to safeguard medicinal plants, and the ayurvedic and other traditional medicinal knowledge in the country. Recognizing their importance, not only as a national heritage, but also as a global asset, the Government decided to formulate a project, and has sought funding from the Global Environmental Facility (GEF), especially to supplement its efforts for preserving these resources in the CHT region. The project is expected to address all the various problem areas, and make an effort for conservation in a sustainable manner.

Orchids

Recently orchids have become immensely popular among urban people. Preliminary studies indicate that there are more than 100 species of orchids found in Bangladesh. Some are located in the Sal forest, Sylhet hill forest and also in the mangrove forests. *Cirrhopetalum roxburghii* is endemic to the litoral forests of Sundarbans. As orchids have caught the attention of businessmen, they are now collected from nature secretly and indiscriminately. Therefore, if steps are not taken to prevent indifferent collection of them, some of the species will be eliminated from the country.

Table 3.4.5 Estimated Water Bodies and Forest Areas in Bangladesh

Water bodies*	
•	4,395,966 hectares of inland water
•	479,735 hectares rivers and canals
•	16,607,000 hectares marine water bodies
Forest land**	
•	2,600,000 hectares (ca. 18% of total land surface) forestland, including village forests and tea gardens
•	670,000 hectares evergreen forest
•	123,000 hectares deciduous forest
•	601,700 hectares natural, and 130,000 hectares coastal and forested mangrove forest
•	270,000 hectares village forest
•	40,000 hectares social forest
•	70,000 hectares tea garden

* Ahmed & Ali, 1996
** Department of Forest, Bangladesh

3.4.3.3 Habitats

Forestry contributes to a great extent to the economic and ecological stability of Bangladesh. According to a recent estimate, total forestlands including plantations, gardens, and homesteads cover about 2,600,000 hectares in Bangladesh, which is 17.87 per cent of the land surface of the country (Table 3.4.5).

The delta has a total of 4,395,966 hectares of inland waters, of which 2,832,792 hectares are flood plain, 146,890 hectares are ponds and tanks, and 610,000 hectares are estuaries and mangroves (Ahmed & Ali, 1996, Table 3.4.5). These water bodies not only provide sanctuary to the inland water fish species, but also to thousands of other plants and animals.

Forests

Most of the forests of Bangladesh are located in the Greater Districts of Chittagong, Chittagong Hill Tracts (CHT), Sylhet, Khulna, Dhaka, Mymensingh, and Tangail. The moist deciduous forests are found in

Table 3.4.6 Types of Forest in Bangladesh

1.	**Hill Forest** Reserved Forest Unclassified State Forest
2.	**Plain-land Forest** Deciduous Forest Village Forest
3	**Mangrove Forest** Sundarban Natural Forest Coastal Afforestation
4.	**Social Forest**
5.	**Tea Gardens**

Source: Department of Forest, Bangladesh

Dhaka, Mymensingh, Rangpur, Dinajpur, and Rajshahi districts. In the coastal areas, plantations have been established on the newly accreted *char* land.

Throughout the country the forestlands are largely devoid of adequate natural cover, except negligible forest pockets. To conserve plants and other biodiversity, the GoB have declared a number of protected areas throughout the country (Table 3.4.7). However, a vast majority of land designated as forests is without tree cover. Most of the protected areas are not properly managed due to lack of proper implementation or enforcement of existing rules, as well as inadequate facilities.

Under the management of the Forest Department, the three main types of forest are hill forest, plain-land forest, and mangrove forest (Table 3.4.6).

Hill forest

The total area of hill forest is 670,000 hectares, which is 4.54 per cent of total land area of the country (Table 3.4.5). The hill forests have been broadly classified as tropical wet-evergreen forest, and tropical semi-evergreen forest. Under hill forests the following types of forests are found:

- Reserved Forests (RF)
- Unclassified State Forests (USF)

The Reserved Forests are those managed by the Forest Department who collect revenue from them. Rest of the hills forest comes under Unclassified State Forests.

Most of the hill forests in Bangladesh are characterized as mixed evergreen forests (Table 3.4.5). In such forests, the tropical evergreen plant communities are mixed with tropical deciduous trees, in association with diverse herbs, shrubs, and bamboo jungles. Forests in Greater Chittagong Hill Tracts, Chittagong, and in Sylhet and Mymensingh districts fall under this category. Usually canopies of different evergreen trees are formed, having three distinct heights and gallery sequences. Among the dominant trees are Garjan (*Dipterocarpus turbinatus*), Uriam (*Bouea oppositifolia*), Civit (*Swintonia floribunda*), Telsur (*Hopea odorata*), Chandul (*Tetrameles nudiflora*), Boilam (*Anisoptera scaphula*), Jarul (*Lagerstroemia speciosa*), Dhaki jaam (*Syzigum grande*), and Chaplaish (*Artocarpus chaplasha*).

Hill forests in the eastern districts of Chittagong, Cox's Bazar, Sylhet, and the CHT region are tropical evergreen or semi-evergreen forest. The most important commercial timber species of the CHT are Jarul, Gamari (*Gmelina arborea*), Garjan, Chaplaish, Toon (*Cedrella microcarpa*), Koroi (*Albizia procera*), Civit, Champa (*Michelia champaca*), Shimul (*Salmalia insignis*), and Chandul.

Apart from evergreen and deciduous forest vegetation, bamboo and savannah type of forests are of immense economic and environmental value. Bamboo grows among various types of forests in CHT and Sylhet. The bamboo is used as a raw material to make pulp for paper mills. It is also used for house construction, and supports many cottage industries. Forests of the savannah type are those where there are practically no trees, and the areas are covered by Sungrass. A very large portion of the Unclassified State Forests consists of this type of forest.

The natural look and character of the CHT forest has been changed due to human intervention through plantation activities. Rubber plantations undertaken by the Bangladesh Forest Industries Development Corporation (BFIDC) have not proven to be environmentally or economically successful. They have played a role in hastening deforestation, and changing the natural character of the CHT forests.

Sal forest

The traditional Sal forest used to extend over Madhupur Tract, as well as the districts of Dhaka, Mymensingh, Rangpur, Dinajpur, and Rajshahi. Now the Madhupur Sal forest is the largest Sal forest patch in the country. In the Sal forest, 70-75 per cent of the trees are Sal (*Shorea robusta*), and the soil looks yellowish-red in color. The other commercially valuable trees in the Sal forest are Koroi (*Albizzia procera*), Chambal (*Artocarpus chaplasha*), Haritaki (*Terminalia chebula*), Bahera (*Terminalia belerica*), and Bajna (*Zanthoxylum rhetsa*).

Most of the Sal forest has been denuded, degraded, and encroached upon by people, or used for plantation of rubber monoculture and mostly exotic commercial fuel-wood species. The demand for Sal and other forest products seems unlimited. Even though now the supply has decreased drastically, Sal trees, including the stumps, are still used as fuel in brick kilns and for industry.

Reed-land Forest

The reed-land forest situated in Sylhet comprises a total area of 23,590 hectares. The forest ranges from swamp forest to mostly reed or Nal (*Phragmites karka*), Kash (*Saccharum spontaneum*), and Ikra (*Saccharum ravinae*), and in some areas there are also permanent water bodies. The reed-land areas are also very rich in faunal diversity. A survey reported 27 mammals, 49 birds, 22 reptiles and 9 amphibians from the reed-land forest. All of them are used as food, medicine, bait, for commercial trade, and recreation. The reed-land flood plains are also rich in fisheries resources. Due to indiscriminate harvesting, the reed populations are declining. The rate of depletion is as high as 60 per cent in particular areas. Therefore, proper management is necessary to protect the reed-land forest.

3.4.3.4 Mangrove Forest Biodiversity

Bangladesh has one of the most biologically resourceful and unique forests known as the Sundarbans. The Sundarbans is the largest mangrove forest in the world. Mangrove forests have a unique combination of terrestrial and aquatic ecosystems. The mangrove forests serve as a natural fence against cyclonic storms and tidal surges, stabilize coastlines, enhance land accretion, and enrich soil near the aquatic environment. The Sundarbans Reserve Forest occupies an area of 601,700 hectares of which 406,900 ha forests, 187,400 ha water (rivers, rivulets, ponds, and canals), 30,100 ha form wildlife sanctuaries, and 4200 hectares are sand bars. It is home to several uniquely adapted flora and fauna, and provides feeding and nursery grounds for many animals. Many animals spend their entire life in the mangroves, whilst others spend some part of it.

The mangrove forest is very rich in biodiversity and supports 334 species of plants, as many as 77 insects of different orders, 7 crabs, 1 lobster, 23 shrimp/ prawns, 400 fish, 8 amphibians, 35 reptiles, 270 birds, and 42 species of mammals. There are about

A view of the Sundarbans biodiversity

13 and 23 species of orchids and medicinal plants, respectively, found in the Sundarbans. It is also the largest honey-producing habitat in the country with giant honey bees (*Apis dorsata*). The best tree for producing honey in the Sundarbans is Khulshi (*Aegiceras comiculatum*).

The Sunderbans is the only remaining habitat of the famous Royal Bengal Tiger *(Panthera tigris)*, and estuarine crocodiles *(Crocodylus porosus)* occur extensively in the rivers. The forest harbors large numbers of threatened wildlife species including Python, King Cobra, Adjutant Stork, White-bellied Sea Eagle, Clawless Otter, Masked Fin-foot, Ring-lizard, and River Terrapin. The Sundarbans is also home to thousands of Spotted deer *(Axis axis)*.

Out of 26 species of mangroves, the two dominant ones are the Sundari *(Heritiera fomes)* and Gewa *(Excoecaria agallocha)*. Among the trees, Gewa and Goran (*Ceriops roxburghiana*) are being used in newsprint mills for paper production, as well as for fuel-wood. The Sundari and Keora (*Sonneratia apetala*) are used as timber woods. Leaves of gol pata *(Nypa fruticans)* are used for thatching. At present, there is no commercial timber felling due to a moratorium imposed by the Government of Bangladesh, with the exception of Gewa and Goran.

Another mangrove forest totally about 21,020.45 acres of land at Chokoria Mangroves in Cox's Bazar has been destroyed mainly due to uncontrolled logging, agricultural expansion, and shrimp culture. There it is pretty difficult to see remnants of mangrove vegetation other than few dead stumps here and there. Along with the forest all other flora and fauna are destroyed from the areas where fish is not also excluded.

3.4.3.5 Wetland Biodiversity in the *Haor* Basin

It is estimated that about 50 per cent or more of the land surface of Bangladesh is wetland, consisting of about 700 rivers, creeks, streams, and other water bodies known locally as *haor, baor, beel* and *khal*. There are also the vast estuarine systems and mangrove swamps of the south and southeast regions, as well as innumerable man-made water bodies of various sizes.

The northeast region of Bangladesh, comprising the flood plains of the *Meghna* tributaries, has a distinct type of wetland that is known as the *Haor* Basin. This basin comprises an area of about 2,450,000 hectares, or 17.5 per cent of the area of Bangladesh. The *haors* are depressions located between two or more rivers, and function as small internal drainage basins. Within the lowest points of the *haor*, there are one or more *beels*, which are lake-like deep depressions retaining water permanently or for a greater part of the year. The biological features in the *haors* are unique and fascinating to observe. In the past the *Haor* Basin biodiversity was very rich, but recently it is diminishing since the environment has degraded so much.

Table 3.4.7 List of Wildlife Sanctuaries (WS), National Parks (NP), and Game Reserves (GR) in Bangladesh

Sl.No.	Status	Area	Forest type
1	Sundarban East (WS)	31226.938 ha	Mangrove forest
2.	Sundarban South (WS)	36970.454 ha	Mangrove forest
3.	Sundarban West (WS)	71502.13 ha	Mangrove forest
4.	Rema Kalenga (WS)	1795.54 ha	Mixed evergreen forest
5.	Char-Kukrimukri (WS)	40 ha	Mangrove forest
6.	Pablakhali (WS)	42,087 ha	Mixed evergreen forest
7.	Teknaf (GR) (Elephant)	11,615 ha	Mixed evergreen forest
8.	Himchari (NP)	1,729 ha	Mixed evergreen forest
9.	Bhawal (NP)	5,022 ha	Deciduous forest
10.	Modhupur (NP)	8436 ha	Deciduous forest
11.	Chunati (WS)	7761 ha	Mixed evergreen forest
12.	Lawachara (NP)	1250 ha	Mixed evergreen forest
13.	Kaptai (NP)	5464.77 ha	Mixed evergreen forest
14	Hazarikhil (WS)*	2903 ha	Mixed evergreen forest
Total		227802.06 ha	

* Not declared
Source: Department of Forest, Bangladesh

Several distinct vegetation zones that are found in the *haors* as follows:

- *Submerged:* The submerged plant community consists of *Hydrilla verticillata, Potamogeton crispus, Naja* spp., *Aponogeton appendiculatus,* and *Ottelia alismoides*. These plants remain permanently under water around the year.
- *Free Floating:* This type of vegetation floats freely in the water. Among the available species found in the water bodies of the country are *Eichhornia crassipes, Utricularia* spp., *Salvinia natans,* and *Salvinia cullata.*
- *Rooted Floating:* These types of plants include *Euryale ferox, Nelumbo nucifera, Trapa maximowiczii, Hygroryza aristata, Limnophila indica, Nymphoides indica,* and *Pseudoraphis minuta*.
- *Sedges and Meadows:* These plants grow at the transition zone, and are basically ecotonal plants. Some of them are terrestrial, some are aquatic, and others are amphibious in nature. These include *Alternanthera philoxeroides, Clinogyne dichotoma, Eclipta alba, Enhydra fluctuans, Fimbristylis dichotoma, Ipomoea aquatica, Ludwigia* spp., *Persicaria* spp., *Scripus erectus, Vetiveria zizanioides,* and *Xanhium indicum.*

Waterfowl make their nests on the floating plants. A total of 284 species of waterfowl were recorded in the Haor Basin (FAP 6, 1993). Despite massive habitat losses, the northeast region of the country is still an important place for migratory waterfowl, principally ducks and shore birds. Various other wildlife, e.g. otters, cormorants, jacanas, coots, egrets, herons, etc., also find this vegetation a safe place for feeding and nesting, as well as for breeding.

The Haor Basin alone produces a remarkable quantity of freshwater fish, and each *haor* acts as a fish sanctuary for several indigenous fish species. Bangladesh has very rich freshwater algal resources, and phycologists have already identified about 150 species.

The swamp forests of the Haor Basin have communities of Hijal (*Barringtonia acutangula*), Karaja or Koroch *(Pongamia pinnata),* Barun *(Crataeva nurvala),* and Gota gamar *(Trewia nudiflora),* but these are very degraded due to overexploitation.

The *haor* systems support major subsistence and commercial fishing, rice growing, grazing grounds for livestock, and also serve as a source of fuel, food and fertilizers for the local populations.

A participatory wetland resource management plan might save the wilderness and functions of the vast *haors* and other wetlands of the country. Local communities should get the highest priority in managing their own resources for both conservation and sustainable utilization.

3.4.3.6 Coastal Biodiversity

Bangladesh has the world's longest beach (710 km) along the Bay of Bengal, filled with a rich and unique coastal biodiversity. It has a great natural ecosystem value in terms of scientific interest, and because of its outstanding aesthetic value. It also provides multiple renewable resources of direct economic benefits to the nation.

The marine resources in the Bay of Bengal waters are yet to be explored fully in terms of biodiversity. About 442 species of finfish, 336 molluscs including 7 edible oysters, and 3 species of lobster have been recorded in the Bay of Bengal, and there are 17 reptiles, and 3 species of mammals (Table 3.4.1).

St. Martin's Island

The southern-most offshore island, St. Martin's, is a small and beautiful coral island located in the Bay of Bengal. The west coast of the island is an important nesting beach for marine turtles in the Bay of Bengal. Two globally threatened species of marine turtle, Olive Ridley and Green turtle, visit the pristine sandy beach to lay their eggs during the winter months of November to January.

The coastal area of St. Martin's is fringed with inter-tidal rocks that support a diverse coral community, associated with fish and invertebrate fauna characteristic of coral reefs. Corals of diverse species are in abundance, ranging from honeycomb, branched, brain coral, and a dozen more. About 66 species of corals from 22 genera have been identified at St. Martin's Island. A rich growth of benthic algae consisting of 168 species belonging to 77 genera was reported from the coral reef of St. Martin's Island.

A wide variety of multicolored coral reef-associated fishes, e.g., moon wrasses, parrot, angel, spotted bat, groupers, rabbit, tiger, snappers, sea horses and soldier fish are very common in the inter-tidal waterlogged areas between coral boulders, or rocks and sand dunes. There are 86 species of coral reef-associated fish belonging to 34 families existing in the waters surrounding St. Martins Island (Tomascik, 1997).

Among the marine fishes, skates, rays, sharks, pomphrets, etc., are the important ones. There are mangrove formations at the southern intertidal mudflats. Nearly 150 species of shorebirds used to visit the mudflats during the winter season, including some of the globally threatened waders such as Spoon-billed Sandpiper, Nordman's Greenshank, Asian Dowitcher, etc., but now their population numbers have decreased.

Table 3.4.8 Institutions in Bangladesh performing Biodiversity- related Research

- All the state run universities (especially the Department of Zoology and Botany)
- Bangladesh Rice Research Institute (BRRI)
- Bangladesh Jute Research Institute (BJRI)
- Bangladesh Tea Research Institute (BTRI)
- Bangladesh Agricultural Research Institute (BARI)
- Bangladesh Fisheries Research Institute (BFRI)
- Bangladesh Forest Research Institute (BFRI)
- Sugarcane Research and Training Institute (SRTI)
- Bangladesh Council of Scientific and Industrial Research (BCSIR) at Chittagong specializes in the medical plant research
- Bangladesh National Herbarium (BNH)
- Department of Environment (DoE)
- Forest Department (FD)
- Department of Fisheries (DoF)

Nijhum Dweep

Nijhum Dweep, an area of 4,232 hectares is located at the confluence of Meghna estuary on the Bay of Bengal, within the Hatiya *thana*, under the territorial jurisdiction of Noakhali Forest Division. It is the habitat for waterfowl, migratory shore birds, and a large number of reptiles and mammals. Its aquatic areas harbour the Ganges River Dolphin.

3.4.4 RESPONSES

The Government of Bangladesh has taken various steps in response to the need for conservation of indigenous biodiversity. Some major ones are as follows.

3.4.4.1 Institutes

There are various research institutes involved in biodiversity-related research as shown in Table 3.4.8. They directly or indirectly help in conservation of biodiversity through various multi-directional research projects.

A national forum, known as Bangladesh National Biodiversity Group (BNBG), was formed on August 1, 1995 to initiate a national database of biodiversity, as well as provide scientific and technical advice on national policy formulation for biodiversity.

Bangladesh National Herbarium
BNH is the repository of plant resources in the country. Researchers preserve plant specimens in dry or wet (in bottle) condition for future reference, research, and other uses. The researchers collect plants from all over the country, identify, and preserve them. Recently, the BNH started a program to compile a Red Data Book of flowering plants of the country based on field study, in conjunction with herbarium and literature surveys on the threatened species.

Other Biodiversity Related Development Partners
Development partners like UNDP, FAO, DFID, IFAD, DANIDA, CARE, EU, USAID, CIDA, and Ford Foundation are involved in the fisheries sector of Bangladesh, with the stated aim of increasing fish production and improving fisheries management. These donors fund studies, institutional development, pilot activities, etc. They also show concern for the rights of the fishermen, and their role in management. Some of the local NGOs are also involved in conservation of biodiversity throughout the country.

3.4.4.2 Policy Response

Bangladesh is a signatory to about 28 environmental treaties, conventions and protocols. Bangladesh signed the Biodiversity Convention at Rio in 1992, and ratified it in 1994. A focus on biodiversity has been emphasized in the Forest Policy and Environment Policy. However, a separate policy on biodiversity is yet to be formulated, and until then various departments of the government are responsible for conservation of biodiversity. The Bangladesh National Biodiversity Strategy and Action Plan is under preparation as a national obligation to the Convention on Biological Diversity.

The Forest and National Environment Policy sets the policy framework for some biodiversity and environmental action, in combination with a set of broad sectoral guidelines. It emphasizes among other things:

- Maintenance of the ecological balance, and overall progress and development of the country through protection and improvement of the environment;
- Identification and control of all types of activities related to pollution and degradation of environment;
- Environmentally sound development in all sectors;
- Sustainable long-term and environmentally congenial utilization of all natural resources; and
- Active association with all environment-related international initiatives.

In order to protect wildlife biodiversity the Bangladesh Wildlife Preservation (Amendment) Act, 1974 is available, where names of protected animals are also enlisted.

In the area of legislation, the Bangladesh Environment Conservation Act (BECA) has articles that expand upon the environmental management and sustainable development goals of the Environmental Policy, 1992. In particular, it defines the environmental regulatory regime and the mandate of DoE in this respect. Among the measures instituted is a provision for the declaration of Ecologically Critical Areas (ECAs) and their management.

Legal and Regulatory Famework
As mentioned above, there are no direct Acts and Rules in Bangladesh regarding conservation of biodiversity. Under these circumstances, the following existing acts and rules have been found relevant to the conservation of biodiversity:

1. The Protection and Conservation of Fish Act, 1950.
2. The Protection and Conservation of Fish Rules, 1985.
3. The Private Fisheries Protection Act, 1889.
4. Bangladesh Fisheries Development Corporation Act, 1973.
5. The Marine Fisheries Ordinance, 1983.
6. The Fisheries Research Institute Ordinance, 1984.
7. Wildlife Preservation Act, 1974 (Amendment Act 1994).
8. Forest (Amendment) Act, 1990.
9. Forest Act, 2000 (Amending Act, 1927).
10. The Environment Conservation Act, 1995.
11. The Environment Conservation Rules, 1997.

3.4.4.3 Conservation Initiatives

Parks and Protected Areas
The IUCN commission has established a system for the classification of protected areas on the basis of management objectives, and a total of 7,734,900 km or 5.19 per cent of the earth's land area are covered under this protected area system, (WEMC, 1992).

The protected areas dispersed throughout the country play a fundamental role in the conservation of species and ecosystem diversity in Bangladesh. The Government uses a variety of different legal and administrative mechanisms to manage national parks and protected areas for the conservation of biodiversity.

The establishment of the three categories of protected areas, namely National Parks, Wildlife Sanctuaries and Game Reserves has been provided through the Bangladesh Wildlife Preservation Act, 1974 (amendment act 1994) . With the goal to conserve the biological diversity of the country, the Government of Bangladesh has declared 14 protected areas (Table 3.4.7) and is considering declaring more. Moreover, the Government of Bangladesh has recently declared 6 areas viz. Cox's Bazar Teknak Sea Beach (10,465 ha), St. Martin's Island (590 ha), Sonadia Island (4,916 ha), Hakaluki *Haor* (183,813 ha), Tanguar Haor (9,727 ha) and Marjat *Baor* (200 ha), as Ecologically Critical Area (ECA) under environmental conservation act, 1995.

Very recently, a part of the Sundarbans forest (59,600 hectares from its East, West and South sites), and 9,772 hectares of Tanguar haor have been designated as Ramsar sites in the country. In addition, since February 4, 1999, UNESCO has classified 139,700 hectares of land in the Sundarbans covering three regions East, West, and South as World Heritage Sites.

Conservation and Development
With respect to conservation activities, government agencies in some countries and territories are undertaking various types of activities, such as designation of protected habitats, regulation of hunting and related activities, improvement of habitats, studies on the breeding, feeding and migration ecology of water birds, and increasing education and awareness. Several international organizations have been involved in bird conservation, such as Birdlife International, Crane Foundation, Wetlands International, IUCN, World Wide Fund For Nature, and Oriental Bird Club.

The Government of Bangladesh has recently initiated a number of programs to manage avifauna, both in wilderness and *in situ.* Worth mentioning are programs for the protection of migratory birds through promulgation of the Bangladesh Wildlife Preservation (Amendment) Act, 1974, and the publication of awareness-building materials. A number of training programs at both local and national levels have been organized for developing human resources, and building institutional capacity. Bangladesh is also a member of Global Tiger Forum, a group that is involved in the conservation of tiger populations.

3.4.4.4 Biodiversity Research Initiatives in Bangladesh

A number of projects having biodiversity components are being implemented in Bangladesh. Some of the noteworthy ones are described below:

National Conservation Strategy (NCS)
The idea for a National Conservation Strategy (NCS) emerged in September 1986. Its primary goal was the sustainable use of natural resources. The National Conservation Strategy Implementation Project 1 (1994-1999) was a five-year project implemented by the Ministry of Environment and Forest (MoEF), with financial and technical support from NORAD and IUCN. Through this NCS Phase 1, one major program was implemented in four distinct ecosystems - tropical and mangrove forest areas, St. Martin's Island, Tangour Haor, and Barind Tract. The main objectives of all these activities are conservation of biodiversity.

Coastal and Wetland Biodiversity Management
Bangladesh has completed a Pre-investment Feasibility (PRIF) study on "Coastal and Wetland Biodiversity Management Project" funded by the Global Environmental Facility (GEF). It was a preparatory initiative to develop a project proposal to implement a reserve, and a multiple-use management program for the protection, sustainable management, and integration of at least three priority biodiversity sites in Bangladesh. The primary focus was to integrate conservation and development, in order to protect and manage the priority areas in a sustainable way. The duration of the project was 15 December 1997 to 31 December 1999. The Project Brief and the outcome of the said PRIF study project have already been approved by the Project Steering Committee,

and subsequently accepted by the GEF. The product of the follow-up project entitled "Coastal and Wetland Biodiversity Management in Cox's Bazar and Hakaluki *Haor (BGD/99/G31)*" has also been prepared, and approved by the GEF council for funding. This project is under process of execution by GoB.

Integrated Coastal Zone Management (ICZM)
In December 1999 the Minister of Water Resources announced the Government's intention to develop an ICZM policy. Among other objectives, the ICZM policy will attempt to rationalize and coordinate more effectively a number of environment and development initiatives taking place in the coastal zone. A number of donors, including the World Bank and the Netherlands government, will be supporting the development of this policy over the coming years.

National Biodiversity Strategy and Action Plan
The GEF Headquarters has already approved the project document and under execution.

Conservation and Management of Medicinal Plants
A project on conservation and management of medicinal plant biodiversity for their sustainable utilization will be executed in Rangamati Hill District. This project is in the process of final approval by GEF. The specific objectives of the project are:

- Development of an inventory of medicinal plants in the project area.
- Documentation of traditional uses by the local people.
- Conservation of medicinal plants and their ecosystem.
- Capacity building of concerned agencies in sustainable use of the medicinal plants.

Sustainable Environment Management Program (SEMP)
SEMP is the response evolving from the concerns, needs, and actions identified through the National Environment Management Action Plan (NEMAP) process. It focuses on community-based resource management in wetlands. In NEMAP several major priority areas of environmental concern were identified, and SEMP has been designed to address these priorities. The program consists of 26 components on five major themes, and is implemented by 22 organizations from the Government, non-government organizations (NGOs), and private sector. The community-based '*Haor* and Floodplain Resource Management Project' is being implemented by IUCN with the Ministry of Environment and Forest, in two well defined degraded areas of *haor* and floodplain ecosystems. The major focus of the program is to involve community people in planning, and implementation of activities for management of natural resources that maintain biodiversity and human well-being.

Management of Aquatic Ecosystem through Community Husbandry (MACH)
The natural resources in the floodplain and wetlands throughout Bangladesh are in decline. Thus, to conserve these resources the GoB and the United States of America have jointly developed a program called MACH. An agreement to implement this program was signed in May 1998. Its goal is to ensure the sustainable productivity of all wetland resources such as water, fish, plant, and wildlife over an entire wetland ecosystem.

Sundarbans Biodiversity Conservation Program
The Asian Development Bank (ADB) funded the project "Biodiversity Conservation in the Sundarbans Reserved Forest." The objective of the project was to establish an effective system for the participatory and sustainable management of the ecosystem of the Sundarbans Reserved Forest (SRF). The scope of the project included: biodiversity conservation, sustainable resource management, community development, participatory resources management program, development of eco-tourism infrastructure, and establishing a new multi-sectoral management agency that will work for an integrated conservation and development approach

Forest Resources Management Project
The World Bank (WB) funded a program on "Forest Resources Management Project" in 1992. The primary objective of the project was to establish and maintain a forest management system that was fully responsive to the economic, environmental, and social goals of the country; and to improve the productivity of government-owned forests in order to meet the country's wood and energy needs as much as possible, while still protecting the environment.

Biodiversity Survey in 13 Protect Areas
A biological survey study was conducted in 13 protected areas by Bangladesh Centre for Advanced

Studies (BCAS), in collaboration with the Forest Department (FD). The survey was conducted to assess the biological resources available in the designated areas. The potential value of each protected area was evaluated through determination of the species present, the relative abundance of the species, and the species diversity. The critical habitats in each of the protected areas were identified for protecting the threatened species, and also for developing protective-area management plans.

3.4.5 SUGGESTED OPTIONS AS FUTURE MEASURES

For the conservation of biodiversity an all out effort is necessary that encompasses the different levels of stakeholders who are involved in its use, study, research, and protection. To this purpose, various steps need to be taken, e.g., education, information dissemination, action programs, preventive measures, and policy decisions. Without proper policy decisions it is absolutely impossible to protect biodiversity. A multi-sectoral policy is required, because conservation of biodiversity involves various stakeholders. To help explore new policy options on biodiversity, related policies should be analyzed and gaps should be identified.

Some suggested measures are:

1) The national policy planning authorities should recognize the necessity for conservation of biodiversity, and ensure multi-sectoral coordination for it.
2) Government agencies involved in biodiversity conservation should be strengthened, and new agencies should be created wherever necessary.
3) Agencies for the survey of fauna and microorganisms need to be created.
4) The Wildlife Conservation Circle should be activated and strengthened.
5) As per the declaration made by the Environment Conservation Act, 1995, an ECA wing should be created in the DoE. The Department of Environment should be strengthened for ECA management.
6) Establishment of a National Institute of Biodiversity.
7) A digitized national database on biodiversity.
8) Development of integrated management systems in the agriculture sector, animal husbandry, poultry management and aquaculture.
9) Awareness about the need for conservation of biodiversity among all sections of society should be encouraged.
10) Conservation regulations should be updated, and enforced strictly.
11) If necessary, revision and reallocation of resources should be made to make development sustainable.
12) Studies and development of environmentally sound biotechnology, and evaluation of the positive and negative effects of biotechnology on biodiversity.
13) Establish a network of ecologically critical areas, and manage them properly. This Ecologically Critical Area Management (ECAM) will have a significant impact on the long-term viability of the country's nationally and globally significant biodiversity resources (Ali and Ahmed, 2000).

3.4.6 CONCLUSION

Biological diversity is crucial for the survival and progress of nature and humanity. According to UNESCO (1994), biological diversity provides resources for food, construction, and raw materials for industry. It provides the basis for improvement of the domesticated species; maintains functions of ecosystems, including evolutionary processes; stores and cycles nutrients essential for life; absorbs and breaks down pollutants, including organic waste, pesticides, and heavy metals; recharges ground water, protects catchment basins, and buffers extreme water conditions; and produces soil and protects it from excessive erosion.

Biological resources and biological diversity form the basis of both the ecology and economy of Bangladesh. The country's agriculture, fisheries, and livestock, along with a number of other sectors are heavily dependent, directly or indirectly, on biological resources.

There is a great potential in Bangladesh for biodiversity-based sustainable development. In spite of threatened wild fauna and flora, there are nearly 10,000 species of plants, animals, and microbial organisms - a good percentage of which are found still in abundance. All out efforts are needed to be taken, so that these biological resources are not over-exploited, and sustainable management plans need to be formulated and implemented.

References

Ahmed, A.T.A. (1995a). Impact of Shrimp Culture on the Coastal Environment of Bangladesh. *Proc. Workshop Coastal Aquaculture Environment Management*, pp 77-82. Cox's Bazar, Bangladesh.

Ahmed, A.T.A. (1995b). Impact of other Sectoral Development on the Inland Capture Fisheries of Bangladesh. *Proceeding of the Fourth Asian Fisheries Forum.* The Fourth Asian Fisheries Forum. China Ocean Press. Beijing, China.

Ahmed, A.T.A. and Ali, M. L. (1996). Fisheries Resources Potential in Bangladesh and Manpower Development for Fisheries Activities. In *"Population Dimension Of Fisheries Development And Management Policies Of Bangladesh"*. Dhaka, Bangladesh.

Ahmed, M. (1995). *Biodiversity Conservation of Bangladesh*. Compilation of Theme Papers on Environmental Studies. Bangladesh Technical Education Board pp 136-150. Dhaka, Bangladesh.

Ahemd, M (1999) Aquatic Pollution and Its Impact on Fisheries. Training Course on Industrial Accidents and Safety Management, IEB, Bangladesh University of Engineering and Technolo gy (BUET), Dhaka, Bangladesh.

Alam, M.Z. (1967). *A report on the survey of insect and mite fauna of Bangladesh (East Pakistan).* Agricultural Research Institute. Dhaka, Bangladesh.

Ali, M.O. and Ahmend, M. (2000). Biodiversity Conservation Vision For Bangladesh, Presented in the Reporting *Workshop on Biodiversity in Bangladesh.* Organized by Environmental Forum of Journalists Bangladesh. National Press Club, Dhaka, Bangladesh.

Ali. M. Y. (1997). *Fish, Water and People*, University Press Ltd. Dhaka, Bangladesh.

CBD (1992). *Convention on Biological Diversity.* Text and Annexes, the Interim Secretariat for the CBD Geneva Executive Centre.

CNRS (1999). Pamphlet on Sea Turtles. Dhaka, Bangladesh.

FAP6 (1993). *Fisheries Specialist Study*. North East Regional Water Management Project. Canadian International Development Agency and the Government of Bangladesh, Dhaka.

Green (1978). Primates of Bangladesh: A Preliminary Survey of Population and Habitat. *Biological Conservation.* 13: 141-160.

Hendrich, H. (1975). The Status of The Tiger (*Panthera tigris* L. 1758) In The Sundarbans Mangrove Forest (Bay of Bangal). *Saugetierk Mitt*. 23(3): 161 – 199.

Husain, K.Z. (1974). *An Introduction to the Wildlife of Bangladesh.* Dhaka, Bangladesh.

Husain, K.Z. (1986). *Eleventh Annual Bangladesh Science Conference Rajshahi University.* March 2-6 Rajshahi, Bangladesh.

Islam, M.A., Mahmud-ul Ameen, Ainun Nishat (eds) (2000). *Red List of Threatened Animals of Bangladesh*. Dhaka, Bangladesh.

IUCN (1994). *Species Survival Commission*. IUCN Red List Category, pp 101. The World Conservation Union. Dhaka, Bangladesh.

IUCN (2000). *Red List of Threatened Animals of Bangladesh.* Eds. Islam, M.A., Ameen, M., and Nishat, A. The World Conservation Union. Dhaka, Bangladesh.

Khan, M.A.R. (1982a). The Distribution Of Mammalian Fauna of Bangladesh. *Nat. Cont. Forestry*, pp 560-575. Dhaka, Bangladesh.

Khan, M.A.R. (1985). *Mammals of Bangladesh a Field Guide.* Dhaka, Bangladesh.

Khan, M.S. (1991). *Towards Sustainable Development: Conservation of Genetic Resources of Bangladesh,* p 35. Ministry of Environment and Forest and National Conservation Strategy of Bangladesh Agricultural Research Council. Dhaka, Bangladesh.

Khan, M.S. and Mia, M.M.K. (1984). *Fiber Plants of Bangladesh (wild and cultivated),* p 35. Bangladesh National Herbarium, Bangladesh Agricultural Research Council. Dhaka, Bangladesh.

Mia, M.M.K. and Huq, A.M. (1986). *Timber Plants of Bangladesh (Wild And Cultivated),* p 71. Bangladesh National Herbarium. Bangladesh Agricultural Research Council. Dhaka, Bangladesh.

Mountfort, G. (1969). *The Vanishing Jungle.* Collins. London, UK.

Pocock, R.I. (1939). *The Fauna Of British India, Including Ceylon And Burma,* (2nd edn.) Mammals. 1 & 2 Taylor of Francis, London, UK.

Prater, S.H. (1971). *The Book Of Indian Mammals*. Bombay Nat. Hist. Soc. India.

Sarker, M.S. and Sarker, N.J. (1988). *Wildlife of Bangladesh – A Systematic List.* Rico Printers. Dhaka., Bangladesh.

Tomascik, T. (1997). *Management Plan for Coral Resource of Narikel Jinjira (St. Martins Island).*

UNESCO (1994). Science Conservation and Sustainable Use. *Biodiversity* No. 7. Paris.

WEMC (1992). *Global Biodiversity: Status of The Earth's Living Resources.* Chapman and Hall. London, UK.

Yusuf, M., Chowdhury, J.U., Wahab, M.A. and Begum, J. (1994). *Medicinal Plants of Bangladesh,* p 340. Bangladesh Council of Scientific and Industrial Research. Dhaka, Bangladesh.

3.5.1 INTRODUCTION

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

The geographical setting of Bangladesh makes the country vulnerable to natural disasters. The mountains and hills bordering almost three-fourths of the country, along with the funnel shaped Bay of Bengal in the south, have made the country a meeting place of life-giving monsoon rains, but also makes it subjected to the catastrophic ravages of natural disasters. Its physiography and river morphology also contribute to recurring disasters. Abnormal rainfall and earthquakes in the adjacent Himalayan range add to the disaster situation. Effects of *El-Nino*-Southern Oscillation (ENSO) and the apprehended climatic change have a great impact on the overall future disaster scenarios.

The task of sustaining the very limited resource base is aggravated by population growth and over exploitation, with consequent environmental degradation. It has been further complicated by natural disasters, which further damage the resource base, including flora and fauna.

Since Bangladesh is a disaster prone country, it is subject to colossal damages to life and property almost every year. The different types of disasters,

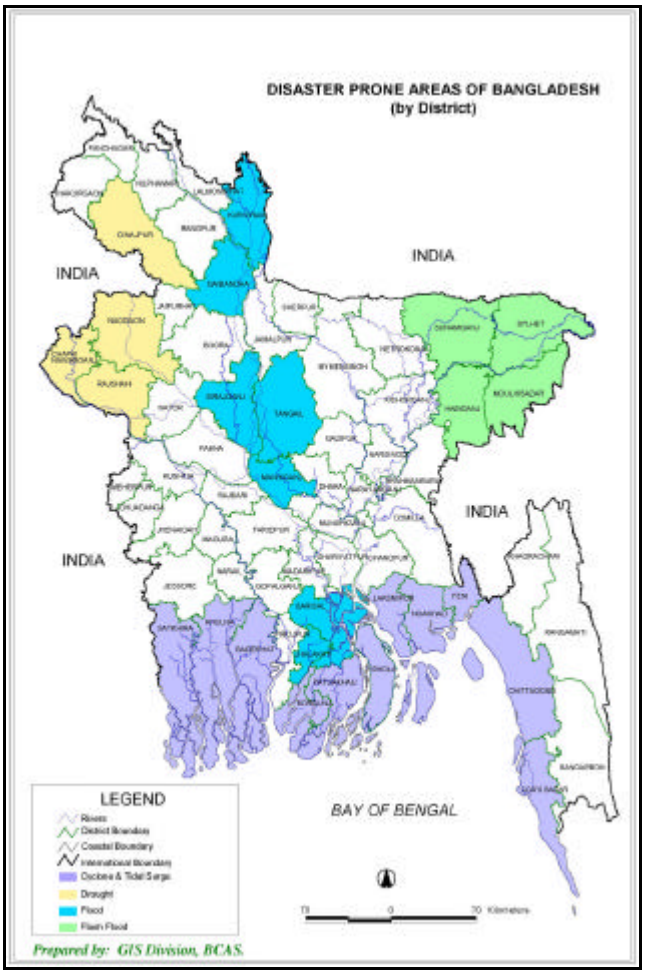
Table 3.5.1 Types of Disasters and their Impacts in Specific Disaster Prone Areas

Types of Disaster	Areas Affected	Impact
Flood	Floodplains of the *Brahmaputra-Jamuna*, the *Ganges-Padma* and the *Meghna river* system	Loss of agricultural production, disruption of communication and livelihood system, injury, damage and destruction of immobile infrastructure, disruption to essential services, national economic loss, evacuation, and loss of human lives and biodiversity, displacement and sufferings of human population and biodiversity
Cyclone and Storm Surge	Coastal areas and offshore islands	Loss of agricultural production, disruption of communication and livelihood system, damage and destruction of immobile infrastructure, injury, national economic loss, loss of biodiversity and human lives, need for evacuation and temporary shelter
Tornado	Scattered areas of the country	Loss of human life and biodiversity, injury, damage and destruction of property, damage of cash crops, disruption in lifestyle, damage to essential services, national economic loss and loss of livelihood
Drought	Almost all areas, especially the Northwest region of the country	Loss of agricultural production, stress on national economy and disruption in life style
Flash Flood	Haor Basins of the North-east region and South-eastern hilly areas	Damage of standing crops, disruption in life style, evacuation and destruction of properties
Hail Storm and Lightning	Any part of the country	Damage and destruction of property, damage and destruction of subsistence and cash crops and loss of livelihood
Erosion	Banks of the Brahmaputra-Jamuna, the *Ganges-Padma* and the *Meghna* river systems	Loss of land, displacement of human population and livestock, disruption of production, evacuation and loss of property
Landslide	Chittagong and Chittagong Hill Tracts	Loss of land, displacement of human population and livestock, evacuation, damage of property and loss of life
Earthquake	Northern and central parts of the country	Damage and destruction of property, loss of life and change in geomorphology

Source: SoE Study Team

and their impact on the affected areas can broadly be summarised as in the accompanying Table 3.5.1.

Figure 3.5.1 Disaster Prone Areas of Bangladesh (by Districts)



Source: GIS Division, BCAS

Flood is a recurring phenomenon in the country, locally termed as *Bonna* or *Borsha* based on the intensity of monsoon rain, magnitude and time of occurrence. When the floodwater damage resources, and disrupt communication and livelihood systems, then it is treated as *Bonna*. Bangladesh gets damaging floods like that of 1988, which bring untold sufferings to millions of people, and result in human deaths, loss of livestock, spread of diseases and hunger, damaged standing crops, destroyed physical and economic infrastructures, damaged fish and shrimp ponds and hatcheries, etc. Cyclone and storm surges occur frequently and cause significant destruction in the coastal areas of the country. Nor'westers and tornadoes also frequently hit different places. Tropical cyclones and tornadoes uproot trees, telephone, telegraph and electricity lines, destroy bridges, culverts, and houses, kill people and domestic animals, leaving serious and adverse effects on the economy as well as on the whole environment. Although this country with monsoon climate has enough rain, droughts frequently take a significant portion out of the agricultural economy of Bangladesh, and cause hunger, instability, and insecurity. The north-western part of the country is vulnerable to drought. Disastrous erosions are mainly associated with the major river systems of the country and are seen along these river banks i.e., the *Brahmaputra-Jamuna*, the *Ganges-Padma*, the Lower *Meghna*, and other rivers.

The effects of a natural disaster, or a combination of more than one natural disaster may be direct loss of life, and certainly damage to physical properties. This requires large resources for disaster management including mitigation, recovery and preparedness. Therefore, the consequences of these natural hazards and the resulting environmental degradation pose a serious threat to the economic development of the country. The situation calls for an effective disaster warning and dissemination system. A timely and accurate alert system about impending disasters will help reduce the loss of life and property (Pramanik, 1991).

Natural disasters cannot be prevented, but the damage can be mitigated with adequate planning and adaptation. The impacts of these disasters vary with their type and magnitude. They also critically depend on institutional strength and response by the different agencies that usually take measures to mitigate and eventually overcome the losses, such as the government and other civil service organizations.

3.5.2 PRESSURES

It has often been pointed out that the worst disasters in the world tend to occur between the Tropic of Cancer and the Tropic of Capricorn, which is coincidentally the area that contains the poorer countries (Carter, 1991). This applies to Bangladesh where the cause of natural disasters is its geographical setting. The lofty Himalayas in the north, and the funnel-like shape of the Bay of Bengal in the south, have made Bangladesh one of the worst victims of the catastrophic ravages of natural disasters like floods, cyclones, storm surges, droughts, etc. Various anthropogenic activities contribute to worsen the situation. Due to recurring

disasters, the country is subject to food shortages in spite of its fertile land, network of rivers, subtropical monsoon climate, and hard working people. A large part of the population is dependent on agricultural production. But harvesting of produce is often affected by extreme natural events and the weather patterns frequently associated with them.

The pressures on the environment that exacerbate the natural disasters in Bangladesh are summarized in Table 3.5.2 and some are described briefly below.

3.5.2.1 Geographical Setting and Physiography

Bangladesh is situated in the Bengal Basin, which is one of the largest geosynclinals in the world. It is bordered on the north by the steep Tertiary Himalayas, on the norhteast and east by the late Tertiary Shillong Plateau, the Tripura hills of lesser elevation and the Naga-Lusai folded belt, and in the west by the moderately high ancient Choto Nagpur plateau.The southern fringe of the basin is not distinct, but the geophysical evidence indicates that it is open towards the Bay of Bengal for a considerable distance. The geographical setting makes Bangladesh particularly vulnerable to cyclones, storm surges and tornadoes.

The Bay of Bengal is the breeding place of catastrophic cyclones. It is situated in the northeastern corner of the Indian Ocean, and is bounded between 5°-22′ North Latitude and 80°-95′ East Longitude. It occupies an area of about 2.2 million sq. km, and is 1,609 km wide, with average depth of more than 7912 meter, and the minimum depth is 4,500 meter (Encyclopedia Britannica, 1980). The Bay of Bengal cyclones mostly originate at latitudes greater than 5°N (near the Andamans). It is presumed that the Inter-Tropical Convergence Zone (ITCZ), which is situated near

Table 3.5.2 Pressures, State, Impacts and Responses of Natural Disaster

Issue	Pressure/Cause	Impacts	Responses
Flood	• Excess flow in monsoon • Improper infrastructural development • 92 per cent of the total catchment area across the boarder • Drainage congestion due to river bed siltation • Deforestation in upper catchment area	• Disruption of communication and livelihood system • Loss of agricultural production • Disruption of essential services • National economic loss • Loss of human lives and biodiversity	• CDMP (Comprehensive Disaster Management Program) • FAP (Flood Action Plan) • National Water Policy • Flood forecast and inundation modeling • Dredging of river bed • Construction of embankments with sluice gates
Drought	• Less and uneven rainfall in dry season and wet season • Non-availability of surface water in dry season • Fluctuation of Ground Water table	• Loss of agricultural production • Stress on national economy due to bad harvesting • Disruption of life style • Reduction of fresh water fish production	• Agricultural research and extention works • Intensive Afforestation Program • Re-excavation of channels and ponds in rural areas • Augmentation of surface water flow • Construction of water reservoir
Cyclone & Storm surge	• Geographical setting of Bangladesh • Coastal configurations and bathymetry of the Bay of Bengal • Location of ITCZ near the equator and its shifting with the apparent movement of the sun across the Bay	• Disruption of communication and livelihood system • Damage and destruction of property • Environmental degradation • Loss of lives and agricultural production • National economic loss	• CDMP (Comprehensive Disaster Management Program) • Strengthening of CPP (Cyclone Preparedness Program) • Local Disaster Action Plans for the grassroot levels along the coastal belt • Awareness building programs for the target group • Reliable and timely warning and effective warning dissemination system
Tornado	• Intense ground heating and low level moisture incursion from the Bay of Bengal during pre and post monsoon • Conjugation of western disturbance with locally developed low pressure	• Loss of lives and biodiversity. • Destruction of property and damage of cash crops • Damage to essential services • National economic loss and loss of livelihood	• Proper radar network • Reliable and timely forecast capability for severe nor'wester • Awareness building programs • Quick search and rescue system
Earthquake	• Geographical location of Bangladesh having major and moderate faults	• Damage and destruction of property • Loss of lives and disruption of life style	• Proper implementation of Building code (1993) • Inventory of equipment for rescue operation

Source: SoE Study Team

the equator, and where winds from the two hemispheres meet, plays a part in the formation of the tropical cyclones.

The storm surge heights are directly related to cyclone intensity, but also to coastal configurations and bathymetry at the time of cyclone landfall. Astronomical influences on the tides can lead to further amplification of surge heights, resulting in severe flooding.

The geographical location of Bangladesh also makes it subject to various climatic features that make it more susceptible to abnormal storms and tornadoes. Intense ground heating during pre-monsoon months can influence the normal seasonal winds that bring rain, the Nor'westers, into forming the swirling, high-speed winds of a tornado. The conjugation of western disturbances with locally developed low pressure also causes tornadoes. The occasional occurrence of Nor'westers, and hence tornadoes, in early June is due to a delay in the onset of the southwest monsoon over the region (Karmakar, 1989).

The location of various major and minor faults near Bangladesh also makes it vulnerable to the effects of earthquakes and tremors.

3.5.2.2 Hydrology

Bangladesh is a land of many rivers, and heavy monsoon rains. Bangladesh is the largest delta in the world, formed by the *Ganges*, the *Brahmaputra*, and the *Meghna* (GBM) river system. This delta is characterized by flat terrain interlaced with an intricate system of about 700 rivers, canals, and streams, with a total length of approximately 22,155 km (BBS 1979, 1998), which carry an enormous quantity of sediment-laden water downstream. Over 92 per cent of the annual runoff generated in the GBM area flows through Bangladesh, which is only about 7 per cent of the total catchment's area (Ahmad, 2000).

Thus, a vast amount of water flows through Bangladesh. It is estimated that every year an average of 870 million acrefeet (MAF) of water flows into the country from India. The amount of rainfall received within the country is estimated at 203 MAF, with evaporation, evapotranspiration, and deep percolation losses probably accounting for about 120MAF. This means that about 953 MAF flows out to sea - from that 914 MAF flows through the *Ganges-Brahmaputra* delta (within Bangladesh), and 39 MAF through the rivers of the Chittagong sub-region and Feni district (Rashid, 1991).

During the peak flow season (July - September) most of the rivers normally overflow their banks onto the low-lying surrounding flat land, which is essential for providing vital moisture and fertility to the soil. However, occasionally abnormal conditions lead to drainage congestion, excessive rainfall run-off, and storm-tidal surges that induce high-magnitude flooding that inundates large areas, and causes widespread damage to crops and property. The devastating floods of the recent past are due to excessive rainfall in the GBM catchment area, and synchronization of peak flow of the Ganges and the Brahmaputra-Jamuna rivers. Effects of *El-Nino*, *La-Nina*, and synchronization of high tide are also considered to be the causes of the flood of 1998. The likelihood of abnormal floods is also increased due to infrastructure development activities that neglect proper concern about environmental impacts and drainage facilities.

An analysis of hydrographs and other hydrological data of a few selected stations indicated the following salient features (Matin and Husain 1988):

- The synchronization of backflows of the major rivers accounts for the floods in the years 1954 (30 days), 1974 (27 days), 1987 (30 days), and 1988 (30 days). The synchronization accentuated the disastrous and catastrophic flood of 1988.
- Frequency analysis shows that the flood level of the Brahmaputra at Bahadurabad and Sirajganj, and the Ganges at Goalondo had a return period of about 100 years. The flood level of the Buriganga at Dhaka, and the Sitalakhya at Narayanganj had a return period in the order of 50 years.
- During 1987, there was an abnormally heavy rainfall throughout the country, whereas in 1988, very heavy rainfall in the upper catchment area occurred.

The mean annual rainfall in Bangladesh varies from about 1400 mm. in the western part of the country, to almost 5000 mm. in the northeast region. There are wide seasonal fluctuations, with about 90 per cent of the rainfall occurring during the four months of the monsoon period (June-September). A number of constraints are inherent

in this monsoon-dependent rainfall and climatic pattern, which can lead to excessive amounts of rainfall and floods, or inadequate rain resulting in drought.

Along with the floodwater, the rivers of Bangladesh carry huge amounts of sediments, an estimated 2.4 billion m.tons/year. The sediments are washed down from highlands on three sides of the Basin, particularly from the Himalayas, where the slopes are steeper and the rocks are less consolidated. Erosion plays an important role in the siltation process, and the water-holding capacity of rivers. The deterioration of the river system due to siltation is one of the causes of floods in Bangladesh.

The river sediments are subjected to coastal dynamic processes generated mainly by river flow, tide, and wind actions. The ultimate result may be additional new land in some places due to accretion, and loss of land in some other places due to erosion. As a result of sedimentation, the formation of *chars* (islands) through accretion takes place. These undesirable *chars* in the river system threaten inland water navigation, cause erosion in the riverbanks, and create other socio-economic problems for people due to land loss and displacement.

Erosion in the coastal regions of Bangladesh is caused by a number of factors, such as high monsoon wind, waves, and currents, strong tidal actions, and storm surges (Ali, 2000).

3.5.2.3 Global Environmental Pressures

The causes of natural disasters in Bangladesh have an international dimension. The 57 main rivers flowing through Bangladesh are trans-boundary; 54 of them have origins in India, and 3 in Myanmar. The upstream deforestation, heavy rainfall, melting of glaciers, and soil erosion play a vital role in causing siltation in riverbeds. This in turn leads to natural disasters like floods, flash floods, etc. The upstream activities also enhance the magnitude of damages caused by these disasters. The upstream withdrawal of water due to the Farakka barrage across the Ganges in India leads to local drought conditions in regions of Bangladesh.

There is firm scientific evidence that largely due to human activities the concentration of greenhouse gases in the earth's atmosphere is increasing. The consequences will be progressive global warming and climate change. Bangladesh is thought to be one of the most vulnerable countries in the world to climate change, and the resultant Sea Level Rise (SLR) that is apprehended.

It is expected that Bangladesh may get warmer and wetter owing to global warming. Higher precipitation may increase the area and depth of flooding, which will require additional measures for protection and adaptation. Other probable pressures include disruption of the monsoon rhythm, prolonged drought, and increased frequency of cyclones. The most serious consequence of climate change for Bangladesh will be a rise in sea level along the Bay of Bengal coast, causing submergence of 10 to 20 per cent of the land (including the Sundarbans), as well as saline intrusion in the rivers.

Bangladesh is one of those poor countries which may face the irony of adapting to and mitigating the consequences of man-made global warming and climate change, which are largely not of their own making; while they have little human, societal, technological, or financial capability for such adaptation and mitigation (Huq *et al.*, 1999). Bangladesh is thought to be one of the most vulnerable countries in the world to Climate Change and Sea Level Rise (SLR). The apprehended Climate Change and SLR will lead to coastal inundation throughout the world, particularly along low-lying coastal areas. In Bangladesh, it is likely to inundate wetlands and lowlands, accelerate coastal erosion, increase the risk of flood and cyclone disasters, change rainfall pattern, create drainage and irrigation problems; and increase salt water intrusion into ground water, rivers, agricultural, and coastal forestlands. This may in turn cause damage to port facilities and coastal embankments/structures, destroy quality farm lands, disrupt mangroves, fisheries and bird habitats, result in loss of recreational beaches, and affect cyclone and storm surge protection measures in the coastal areas (Ali, 2000).

The SLR might make an impact on the country as a whole by inundating one-tenth of the total land area along the coastal belt. If this happens, about ten million people living in the coastal areas of Bangladesh will be forced to migrate further inland. This will put a tremendous population pressure on the mainland.

3.5.3 STATE OF NATURAL DISASTERS

This section, describes the state of various natural disasters which visit Bangladesh frequently and an attempt has been made to elaborate some general causes related to these disasters.

3.5.3.1 Floods

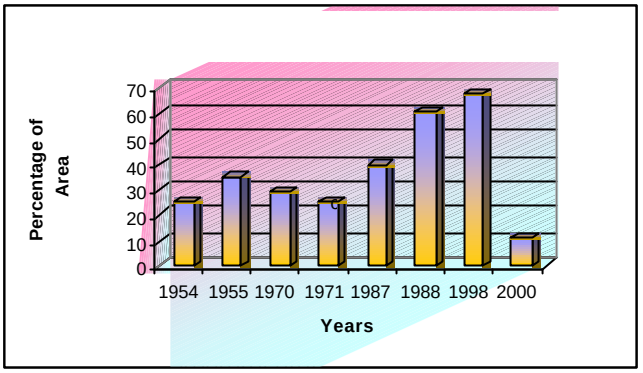
Bangladesh is a land of many rivers, and heavy monsoon rains. Therefore, the country is subject to inundation by overflow from the riverbanks due to drainage congestion, rainfall run-off, and storm-tidal surges. Some 30 to 35 per cent of the total land surface is flooded every year during the wet monsoon (Hossain *et. al.,* 1987 and Milliman *et. al.,* 1989). These normal floods are considered a blessing for Bangladesh-providing vital moisture and fertility to the soil through the alluvial silt deposition. Only abnormal floods are considered disastrous, i.e., the high-magnitude events that inundate large areas, and cause widespread damage to crops and properties.

Flood is more or less a recurring phenomenon in Bangladesh, and often within tolerable limits. Occasionally, it becomes devastating. In 1997, 1988, 1998, and 2000, Bangladesh faced unprecedented floods, causing massive loss of life and property.

During the peak flow season (July, August and September), most of the rivers overflow their banks, and deposit silt on the flood plains - providing vital moisture and fertility to the soil. Thus, the normal floods are considered a blessing for Bangladesh. Only abnormal floods are considered disastrous, i.e., the high-magnitude events that inundate large areas, and cause widespread damage to crops and properties. In the years 1988 and 1998, two devastating floods inundated more than 65 per cent of the geographical area of the country. In the year 2000, Bangladesh faced an unusual flood over its usually flood-free southwestern plain, which also caused loss of life and massive damage to property. Figure 3.5.2 shows percentage of total flood affected areas of the country for some selected years.

Flood is a recurring phenomena

Figure 3.5.2 Flood Affected Areas of Some Selected Years



Source : Miah, 1988, DMB, 2000

The 1988 flood affected about two-third area of the country. Extensive studies by various authors have shown that the area of flooding at different times, varied from 31 per cent to 85 per cent of the total area of the country (Bashar, 1988, Choudhury, 1988, Matin and Hussain, 1988, Pramanik, 1988, and Rashid and Pramanik, 1990).

Causes of Devastating Floods

- Excessive rainfall in the catchment area
- Synchronization of the peak water levels of all the major rivers of Bangladesh.
- Sometimes solar eclipse retards the outflow of water drainage by raising the tidal level.
- Earthquakes cause tectonic anomaly in the Himalayan region and the Bay of Bengal.
- Infrastructure development without adequate drainage facilities.

During the 1988 flood, 8 out of 10 stations in the Brahmaputra basin exceeded the flood level of 1987, and for the Ganges basin that occurred in 5 out of 9 stations. The flood level of the Ganges upstream of Hardinge Bridge was higher in 1987, than in the 1988 flood. Flood-flow of the Ganges was also higher in the 1987 flood. In addition, in the southeastern hill basin, the flood level of all the streams were higher in 1987, than in 1988. During 1987 an area of 57,270 sq. km was inundated, whereas in 1988 an area of 81,831 sq. km was inundated.

The flood of 1998 is considered one of the century's longest and worst natural disasters ever experienced in Bangladesh. Flooding occurred from July 12 to September 14, with duration of 65 days, and affected about 67 per cent area of the country. This devastating flood caused an enormous impact on the national economy, in addition to hardships for people, and disrupted livelihood systems in urban and rural areas.

The devastating floods of the recent past are due to excessive rainfall in the GBM catchment area, and synchronization of peak flow of the Ganges and the *Brahmaputra-Jamuna* rivers. Effects of *El-Nino*, *La-Nina*, and synchronization of high tide are also considered to be the causes of the flood of 1998. Major investment on flood protection in the country began after the devastating flood of 1988.

3.5.3.2 Cyclones and Storm Surges

Cyclones can cause immense loss of life and destruction of property during pre-monsoon (April-May), and post-monsoon (October-November.) periods.

The Bay of Bengal is the breeding place of catastrophic cyclones. It is presumed that the Inter-Tropical Convergence Zone (ITCZ), which is situated near the equator, and where winds from the two hemispheres meet, plays a vital part in the formation of the tropical cyclones in this area.

Tropical cyclones derive their energy from warm moisture of the sea and to sustain this energy, sea surface temperature needs to be at least 26°C. While developing, tropical depression needs a continuing spiral inflow to supply momentum and water vapour to the spinning vortex (Crane 1988).

Cyclones in the Indo-Bangladesh-Pakistan sub-continent are classified according to their intensity of wind speeds. Tracks of cyclones in the Bay of Bengal show that normally cyclones at their initial stages move at a rate of 8-16 km/hour, and in their final stages at 24-32 km/hour, or even up to 48 km/hour. Table 3.5.3 depicts the nomenclature of cyclone.

Table 3.5.3 Nomenclature of Cyclone

Depression	winds up to 62 km/hour
Cyclonic storm	winds 63-87 km/hour
Severe cyclonic storm	winds 88-117 km/hour
Severe cyclonic storm of hurricane intensity	winds above 117 km/hour

Source: Reviewer's comments

Table 3.5.4 Major Cyclones that hit Bangladesh Coast

Date		Maximum Wind speed (km/hr)	Storm Surge height (Metre)
30 October	1960	211	4.6-6.1
30 May	1961	160	6.1-8.8
28 May	1963	203	4.2-5.2
11 May	1965	160	6.1-7.6
15 December	1965	211	4.6-6.1
1 November	1966	146	4.6-9.1
23 October	1970	163	3.0-4.9
12 November	1970	224	6.1-9.1
25 May	1985	154	3.0-4.9
29 November	1988	160	3.0-4.0
29 April	1991	225	6.0-7.5
2 May	1994	210	2.0-3.0
25 November	1995	140	2.0-3.0
19 May	1997	220	3.1-4.2

Source: Chowdhury 1987, 1991 and Bangladesh Meteorological Department 1988, BBS, 1998

Cyclones in the Bay of Bengal usually move north-west in the beginning, and then gradually re-curve to move northeastwards, but this pattern is not uniformly followed. The cyclones usually decay after crossing land, causing colossal losses to life and damages to property in the coastal region.

Heavy rains accompanying cyclones, and the tidal waves due to wind effects, called storm surges, cause most of the damages. Storm surge heights are directly related to cyclone intensity. Besides that, coastal configurations and bathymetry are also related to surge heights at the time of cyclone landfall. Astronomical tides in combination with storm surges lead to further amplification of surge heights, resulting in severe flooding.

An average of 1-3 severe to moderate cyclonic storms hit Bangladesh each year, with associated storm surges as much as 13 meters higher than normal in extreme cases, which can reach as far as 200 km inland (Milliman *et al.* 1989). Catastrophic cyclones, which originated in the Bay of Bengal and hit Bangladesh from 1960 to 1997, are presented in the Table 3.5.4 along with their dates, maximum wind speed, and heights of storm surge.

3.5.3.3 Droughts

Drought is an abnormal condition where there is lack of sufficient water to meet the normal needs of agriculture, livestock, industry, or for human use. While generally associated with semi-arid or desert

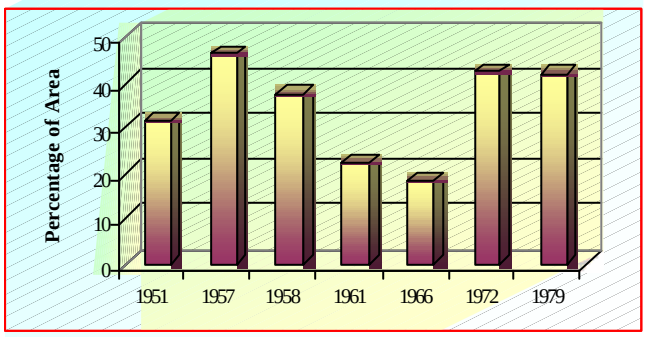
climates, drought can also occur in areas that normally enjoy adequate rainfall, and moisture levels (ADB, 1991). Drought is the result of insufficient or no rainfall for an extended period, and causes a considerable hydrological (water) imbalance. The ensuing water shortage leads to stream flow reduction, depletion of ground water and soil moisture, and hence, crop damage. In drought conditions, evaporation and transpiration exceed normal levels. If it continues for a prolonged period, a serious threat is posed to agricultural production. In agricultural context drought affects the rice production most. Due to drought severity, crop loss ranges between 20->60 per cent for T. Aman and other rice varieties (Iqbal, 2000). It is one of the most insidious causes of human misery.

Basically, there are three types of droughts:

- Permanent drought characterizes regions with the driest climate, having sparse vegetation that is adapted to aridity. Agriculture cannot be practised without irrigation.
- Seasonal drought occurs due to abnormal rainfall shortage in places where there are well-defined annual rainy and dry seasons.
- Unpredictable drought involves an abnormal rainfall failure, mostly in localized areas of humid and sub-humid climate.

Drought conditions due to deficiency in rainfall affect different parts of Bangladesh mostly during the pre-monsoon and post-monsoon periods. One study has shown (Figure 3.5.3) that from 1949 to 1979, drought conditions had never affected the entire country and total population in any drought year. The drought of 1979 was one of the severest in recent times. The percentage of drought-affected areas was 31.63 per cent in 1951, 46.54 per cent in 1957, 37.47 per cent in 1958, 22.39 per cent in 1961, 18.42 per cent in 1966, 42.48 per cent in 1972, and 42.04 per cent in 1979 (Chowdhury and Hussain 1981). During 1981 and 1982, drought affected the production of the monsoon crop only.

Figure 3.5.3 Drought Affected Area



Source: BCAS Compilation

3.5.3.4 Abnormal Rainfall, Hailstorms, and Lightning

Monsoon depressions that form in the Bay of Bengal move landward, and cause monsoon rain to be spread widely throughout the country.

The mean annual rainfall in Bangladesh varies from about 1400 mm. in the western part of the country, to almost 5000 mm. in the northeast region. There are wide seasonal fluctuations, with about 90 per cent of the rainfall occurring during the four months of the monsoon period (June - September). Monsoon depressions that form in the Bay of Bengal move landward, and cause monsoon rain to be spread widely throughout the country. Based on the area of formation, structure, intensity, and frequency of the monsoon depressions, the total rainfall during the monsoon period can be predicted. In spite of an overall abundance of rainfall during monsoon, at times serious rainfall shortage leads to droughts. It is not unusual for regions in Bangladesh to experience inadequate rainfall during the monsoon, while little rain during the dry season (October-March) is quite common, too. A number of constraints are inherent in the monsoon rainfall, and climatic pattern. In addition, uncertainty in patterns of pre-monsoon showers, lightning, and hail cause a tremendous impact on human life, and agricultural production.

The month-to-month and year-to-year variations in the atmospheric parameters like rainfall, temperature, humidity, etc., cause substantial variations in crop yields. Therefore, in Bangladesh the patterns of life, and cultivation practices have traditionally been adapted to seasonal variability in climatic characteristics.

3.5.3.5 Nor'westers and Tornadoes

The two transitional periods between southwest and northeast monsoons over the Indian sub-continent are characterised by local severe storms. The transitional periods are usually referred to as pre-monsoon (March-May), and post-monsoon (October-November). It is the pre-monsoon period when most of the abnormal rainfall or drought conditions frequently occur in different parts of Bangladesh. Also

there are locally severe seasonal storms, popularly known as Nor'westers *(Kalbaishakhi)*. Severe Nor'westers are generally associated with tornadoes. The tornado forms within the Nor'wester, and moves along the direction of the squall of the mother storm.

The frequency of Nor'westers usually reaches a maximum in April, whereas there are few in May, and minimum in March. Nor'westers and tornadoes are more frequent in the afternoon. Table 3.5.5 shows some of the devastating Nor'westers and Tornadoes that hit Bangladesh. Nor'westers may occur in late February due to early withdrawal of winter from Bangladesh, Bihar, West Bengal, Assam, and adjoining areas. The occasional occurrence of Nor'westers in early June is due to delay in the onset of the southwest monsoon over the region (Karmakar, 1989).

Table 3.5.5 Some of the Devastating Nor'westers and Tornadoes

14 April 1969	Demra (Dhaka)
17 April 1973	Manikganj (Dhaka)
10 April 1974	Faridpur
11 April 1974	Bogra
09 May 1976	Narayanganj
01 April 1977	Faridpur
26 April 1989	Saturia (Manikganj)

Source: SoE Study Team

Wind-speeds in Nor'westers usually do not exceed 113-130 km/hr (70-80 miles/hr), though often their speeds exceed 162 km/hr (100 miles/hr). When the winds become whirling with funnel shaped cloud having speed at several hundred kilometers or miles per hour, then they are termed tornadoes. Nor'westers bring much needed pre-monsoon rain. They can also cause a lot of havoc and destruction. Tornadoes are suddenly formed and are extremely localized in nature and of brief duration. Thus, it is very difficult to locate them or forecast their occurrence with the present techniques available. However, high-resolution satellite pictures, suitable radar, and a network of densely spaced meteorological observatories could be useful for the prediction or warning of Nor'westers and tornadoes.

3.5.3.6 Earthquakes

The north and northeastern parts of Bangladesh are the most active seismic zones, and had experienced earthquakes of moderate to high intensity in the past. The great earthquake of 1897 had its epicentre in the Shillong Plateau of India, and caused widespread damage in adjacent areas of what was then known as Bengal. Two other major earthquakes that caused severe damage in areas adjacent to the epicentres were in 1885, known as the Bengal Earthquake, and in Srimangal in 1918. In addition, major earthquakes occurred in Bangladesh, and surrounding areas in the years 1833, 1897, 1906, 1918, 1923, 1926, 1927, 1930, 1934, 1939, 1941, 1943, 1947, 1950, 1951, 1954, 1957, 1962, 1965, and 1988 (Karmakar, 1989). Earthquakes with magnitudes between 7.0 and 8.7 on the Richter scale have been experienced in this country, but they are rare events.

3.5.3.7 Erosion

Erosion in Bangladesh is a regular and recurring phenomenon. Erosion of land surfaces, riverbanks, and coastal areas is already causing serious problems for the country. An increase in rainfall in summer is apprehended due to climate change, and this would in turn increase the surface erosion. Land erosion will intensify through current deforestation, and other land use practices (such as *Jhum* cultivation).

Riverbank erosion is a serious problem in Bangladesh. It is a process largely controlled by river dynamics. The disruption in the life of many local communities is almost a continuous process, due to riverbank erosion, and the changing course

River bank erosion

Table 3.5.6 Some Historical Changes of Physiography and River Morphology in Bangladesh

- The change of course of the Teesta from the Ganges to the Brahmaputra during the flood of 1787 (Vas 1911, Chowdhury 1959, Rashid 1977 and Pramanik and Gafoor 1981)
- Recurring floods in Rangpur, Bogra and Pabna districts between 1787 and 1830 accentuated the process of course changes of the Brahmaputra from the old Brahmaputra, which flowed past Mymensingh town and joined the Meghna at Bhairab Bazar, to the Jhenaidah, later developed into the Jamuna (Chowdhury 1959, Ahmad 1968 and Al-Husainy 1976)
- The gradual shifting of the courses of the Ganges from the Hooghly to the present course is controversial (Chowdhury 1959, 1964, Morgan and McIntire 1959 and Coleman 1969)
- The Ganges (Padma) flowed separately to the Bay of Bengal through Tetulia channel during Rennell's survey (1764 -1772). It has changed to its present course by joining the Meghna near Chandpur (Chowdhury 1959, Ahmad 1968 and Chowdhury 1979)
- The 1762 earthquake uplifted the Madhupur tract creating the Sylhet basin through subsidence compensatory to the elevation of the Madhupur tract (Fergusson 1863, Morgan and McIntire 1959). This is also controversial
- The earthquake of Assam in 1950 has caused a change in the Swatch of No Ground and other deep seated rift valleys in the Basin (Kibria 1970)

of rivers. During floods, riverbank erosion becomes very acute, and leads to loss of valuable land.

Of equal if not more concern is the coastal erosion. Globally, 70 per cent of the world's coastline has shown net erosion over the last few decades; less than 10 per cent has net degradation; and the remaining 20 per cent has remained relatively stable. Erosion in the coastal regions of Bangladesh is caused by a number of factors, such as high monsoon wind, waves, and currents, strong tidal actions, and storm surges (Ali, 2000).

3.5.4 IMPACT OF NATURAL DISASTERS

Natural disasters have a tremendous impact on the overall economy of the country. Apart from the instant impacts, natural disasters can also leave long-term impacts. Some significant historical changes induced by major disasters in Bangladesh and adjacent regions are presented in Table 3.5.6.

Almost every year due to natural disasters and climatic hazards, Bangladesh is subject to colossal loss of life and damage of property. All the national planning efforts for development are disrupted by these calamities that leave behind damaged infrastructure facilities, physical assets and land. The human suffering goes beyond description.

The impact of natural disasters not only varies with their type and magnitude, but also critically depends on institutional strength and response to disasters by different branches of the government, as well as community-based organizations. For example, the intensities of the 1991 and 1997 cyclones were of the same magnitude. In the 1991 cyclone, more than 13.7 million people were affected, approximately 138,882 people died, and 139,058 people were injured; and the total loss of livestock and poultry was about one million. On the other hand, the number of human deaths were only 134 from the cyclone in 1997, and 0.4 million people were affected. Loss minimization was only possible due to accurate and timely forecasting, adequate proper warning dissemination, social mobilization, proper coordination by the government, and other institutional backup.

The effects of the devastating flood of 1988 were enormous. According to the World Bank, 45 million people were affected - with 1600 deaths directly attributed to it, and another 735 deaths occurred subsequently as a result of diarrheal diseases. Damage to summer rice crops was estimated at about 1.6 million tons, and loss of physical and economic infrastructure was extensive. About 2,500 km of flood control embankments, 23,500 units of minor irrigation equipment, 10,000 km of local roads, a substantial proportion of national highways and railways,

Table 3.5.7 Damage to Rice Crops due to Drought

Year	Damage
1978	0.7 million tons of *Aman* rice due to rain deficit in August and September
1979	0.6 million tons of *Aus* rice, 0.3 million tons of *Aman* rice, and 0.4 million tons of *Boro* rice crops
1981	0.12 million tons of *Aus*, and 1.3 million tons of *Aman* rice
1982	0.4 million tons of *Aman* rice due to rain deficit in October

Source: Hamid, 1991

several hundred bridges, over 19,000 educational institutes, 1,468 health structures, and 7.2 million housing units were affected by the flood.

In the 1998 flood, 918 people lost their lives, and 242,500 people were sick. Standing crops of 32,31,721 acres were fully or partially damaged. The losses of domestic animals such as cattle, goats, and poultry were 3928, 7041, and 313058, respectively (DMB, 1998). According to the Disaster Management Bureau, the loss of standing crops, including paddy, was estimated at Taka 33.05 billion. BIDS studies revealed that the loss to the agriculture sector was Taka 50.52 billion, of which the losses from rice and other crops were Taka 43.77 billion; and Taka 6.75 billion for fisheries, livestock, etc. The discrepancy between the estimates is mainly due to estimation methodology, and coverage.

Drought is a spatially limited phenomenon affecting the northwestern part of the country. Loss of crop yield is the major impact of drought, and affects the economy of Bangladesh badly. Damage to crops due to drought for a few selected years is presented in Table 3.5.7.

Resources worth an estimated US$25 billion have been destroyed by natural calamities in Bangladesh from 1947 to 1991 (Rahman, 1989).

3.5.4.1 Climate Change Impacts

There is no denying the fact now that the climate system is changing across the globe. This change is attributed to the net effect of individual and interactive effects of global changes in atmospheric composition, land use, biological diversity, and climate. The present concerns regarding the greenhouse effect, and depletion of the ozone layer causing global warming will definitely further aggravate the natural disaster situation in the future.

Bangladesh is one of those poor countries which may face the irony of adapting to and mitigating the consequences of man-made global warming and climate change, which are largely not of their own making; while they have little human, societal, technological, or financial capability for such adaptation and mitigation (Huq, *et al.*, 1999). The possible sea level rise will make an impact on the country as a whole by inundating one-tenth of the total land area along the coastal belt. If this happens, about ten million people living in the coastal areas of Bangladesh will be forced to migrate further inland. This will put a tremendous population pressure on the mainland.

SLR would inundate the low-lying areas of the country, displacing human habitat and shrinking agricultural and forestlands. It is likely to inundate wetlands and lowlands, accelerate coastal erosion, increase the risk of flood disasters, create drainage and irrigation problems; and increase salt water intrusion into ground water, rivers, agricultural, and coastal forestlands. This may in turn cause damage to port facilities and coastal embankments/ structures, destroy quality farm lands, disrupt mangroves, fisheries and bird habitats, result in loss of recreational beaches, and affect cyclone and storm surge protection measures in the coastal areas (Ali, 2000).

Some of the main impacts of global warming and climate change on Bangladesh, which will be manifested as natural disasters are discussed in the following section.

3.5.4.2 Agriculture

Many natural ecosystems are likely to change as a consequence of climate change. Agriculture is a major sector of the country's economy. There is no denying the fact now that the climate pattern is changing across the globe. This change is attributed to the net effect of individual and interactive effects of changes in atmospheric composition, land use, biological diversity, and climate. Many natural ecosystems are also likely to change as a consequence of climate change. Since climate factors strongly interact to affect crop yields, it is likely that climate change will affect crop production. The question remains as to how much, where, and whether the effect would be positive or negative (Huq *et al.*, 1999).

It is believed that climate change will increase the disparities in cereal production between developed and developing countries. The production in the developed world would benefit from climate change, while that in developing nations would decline (Walker and Steffen, 1997). Farm-level adaptation would be inadequate in reducing the disparities. It is also reported that even an extensive farm-level adaptation in the agricultural sector would not entirely prevent negative effects. In

general, the tropical and subtropical countries would be more vulnerable to the potential impacts of global warming through effects on crops, soils, insects, weeds, and diseases. On the other hand, elevated carbon-dioxide (CO_2) concentrations will have beneficial effects on crop production. Beneficial effect will however be less when there is rise in temperature.

Over thirty per cent of the net available cultivable land of Bangladesh is located in the coastal areas. But it has been observed that all the coastal cultivable lands are not being utilized for crop production, mostly due to soil salinity. Increased soil salinity limits growth of standing crops and affects overall crop production, and also makes the soil unsuitable for many potential crops. Soil salinity has been considered a major constraint to food grain production in coastal areas of the country (Huq, *et al.*, 1999).

It is believed that the impact of climate on physical systems, in combination with the effect of sea level rise, would cause a net increase in salinity in the already affected soils of the coastal regions. A GCM modeling approach has indicated that under changed climate conditions the index of aridity will increase during winter (Huq, *et al.*, 1999). As a result, an increased rate of desiccation in topsoil leading to higher rates of capillary action would be observed. Hence, the salinity problem would be accentuated by the impacts of climate change and sea level rise. The extent of increase in soil salinity in a particular area within the coastal zone would determine the extent of crop loss.

Less rainfall during winter due to climate change will lead to a decrease in moisture content of the topsoil, as well as less recharging of the ground water. Higher evaporation would cause worse drought-like conditions. In summer, increased precipitation will worsen the flood situation, which will have a negative effect on agricultural production. Although the increase in CO_2 will have a positive effect on food production, the other negative impacts are likely to dominate.

Studies of 10-day average behaviour of atmospheric parameters, crop phonology, and yields on a systematic basis on a localized scale could depict climatic patterns, and their effect on agricultural production.

Other factors needing study are:

- Timing of onset and withdrawal of the monsoon in a particular year, and its impact on agricultural production.
- Number of nor'westers and tornadoes during pre-monsoon periods, and the effect on the crop phonology, particularly, in the *Aus* crop-growing season.
- Adjustment of cropping patterns based on environmental and climatic variability, and an agro-ecological zoning approach.

3.5.4.3 Salinity Intrusion

Over thirty per cent of the net available cultivable land of Bangladesh is located in the coastal areas. But it has been observed that all the coastal cultivable lands are not being utilized for crop production, mostly due to soil salinity. Increased soil salinity limits growth of standing crops and affects overall crop production, and also makes the soil unsuitable for many potential crops. Soil salinity has been considered a major constraint to food grain production in coastal areas of the country (Huq, *et al.*, 1999).

It is believed that the impact of climate on physical systems, in combination with the effect of sea level rise, would cause a net increase in salinity in the already affected soils of the coastal regions. The apprehended sea level rise would bring more of the coastal area under inundation. Coastal waters are likely to become more saline, and soil salinity will increase. In addition, even groundwater aquifers will face salinity intrusion. Winter crops in the coastal area that depend on groundwater for irrigation would be negatively affected. Agriculture, forestry, and fisheries might face severe adverse effects due to increased water and soil salinity. The extent of increase in soil salinity in a particular area within the coastal zone would determine the extent of crop loss.

Reduced water flow from upland during winters will accelerate the inland saline water intrusion. A GCM modeling approach has indicated that under changed climate conditions the index of aridity will increase during winter (Huq, *et al.*, 1999). As a result, an increased rate of desiccation in topsoil leading to higher rates of capillary action would be observed.

3.5.4.4 Forests

The forests of Bangladesh are under tremendous threat due to a number of anthropogenic and natural reasons. Various activities like increased consumption of forest products, human encroachment, deforestation and deliberate thinning, combined with natural disasters, and the consequences of low flows in distributaries of the Ganges due to water withdrawn at the Farakka barrage in India during lean season, are already causing serious problems for the regeneration and growth of different forest species. In addition apprehended climate change and sea level rise together would cause adverse impacts on the remainder of the forests.

Since the productivity and well being of forest species depend on a number of climate parameters, including temperature and precipitation, there are reasons to believe that the forest ecosystems of Bangladesh would also be affected significantly due to impacts of climate change and sea level rise (Huq, et al., 1999). More frequent and prolonged floods will affect the forest ecosystems. Increased evaporation during winter will cause moisture stress in drier areas.

The only mangrove forest in the country, the Sundarbans, will mostly be affected. The rise in sea level and availability of less fresh water, particularly during winter when rainfall will be less, will cause inland intrusion of saline water. As a result, many mangrove species intolerant of increased salinity will be threatened. In addition, highly dense human settlements just outside the mangrove areas will restrict the expansion of the mangrove towards less saline areas. The shrinking of the mangrove areas will have an overall adverse effect on the country's economy and ecosystem (Ali, 2000). Many industries that depend on raw materials from the Sunderbans will have to be closed down, creating large unemployment. In addition, the survival of a wide range of biodiversity, including mammals, birds, amphibians, reptiles, crustaceans, and above all, the Royal Bengal Tiger will be threatened. The coastal length covered by the mangrove forest will be exposed to cyclones, storm surges, and erosion.

3.5.4.5 Fisheries

According to the World Bank (1989), Bangladesh is the world leader in freshwater fish production per unit area, with 4,016 kg/km2 of water bodies and a per capita fish production of about 5.5 kg In the inland open-water system of Bangladesh there exist 260 species of finfish, belonging to 55 families (Rahman, 1989); about 63 species of palaemonid and penaeid prawn; and several species of crab, belonging to the family Potamonidae, also occur. There are 31 species of turtles and tortoises found, of which 24 live in freshwater (Huq, *et al*, 1999).

From time immemorial fish and fisheries have played a very significant role in the nutrition, culture, and economy of Bangladesh. According to a local adage that reflects the role of fish in the food habit, diet, and nutrition of the people, '*Mache-Bhate Bangali'*, i.e., a Bengali body is made up of fish and rice. Currently, about 80 per cent of the daily animal protein intake in the diet of the people comes from fish. It is estimated that the fisheries sector contributes about 3.5 per cent of the GDP of Bangladesh. Within the Agriculture sector, the fisheries sector accounted for 6.9 per cent of the gross value added. Fisheries provide full time employment to an estimated 2.0 million people.

There is no study in Bangladesh to assess climate change-induced vulnerability of the fisheries sub-sector as yet, particularly on the physiology and ecology of indigenous species of finfish or prawn. Without such studies, it is very difficult to state or predict the likely effects of climate change on different fish or prawn populations, and the fisheries based on them (Huq, *et al.*, 1999).

However, it is predicted that SLR will cause a reduction in fish production by reducing the freshwater fishing area. Decreased rainfall and river runoff, and increased evaporation during winter will also reduce the winter fishing area. Pond culture in the coastal area will be affected by intrusion of salt water into the ponds, unless embankments are made around them. Shrimp farming in the coastal area is a lucrative business, but increase in salinity is likely to jeopardize it as well (Ali, 2000).

3.5.4.6 Ecosystem and Biodiversity

Climate change, with the concomitant increase in temperature and sea level rise, is a real threat to the whole ecosystem and biodiversity of the country, especially the Sundarbans. The Sundarbans might be completely inundated by a one-meter rise in sea level. The area may shrink and many flora and fauna species may face extinction. The possible water stress during winter, and excess water during summer will

also have negative impacts on ecosystems and bio-diversity. The ecosystem of the only coral island, the Narikel Zinzira, will also be affected.

3.5.5 RESPONSES

The modern concept is that there exists a whole process of risk minimization activities that have been identified to address crucial elements of disaster management, which include its prevention or mitigation, preparedness, response, recovery, and development. Based on this realization, and in order to design the institutional and functional arrangements for disaster management, the Government of Bangladesh (GoB) has taken initiatives to frame a disaster management policy. This policy would take care of all aspects, such as accurate definition of disaster threats, organizational arrangements required to prepare responses to and recover from disaster events, assessment of resources available to deal with threats, and recognition of ways for the national disaster management policy to interlock with other national development policies. Along with the policy, a well planned, carefully designed, and action-oriented detailed plan for disaster management is also in the process of preparation. This is of paramount importance to Bangladesh both at national and local levels, for a coordinated and effective effort to cope with the disaster situation. Although climate change is a long-term process, the implications for Bangladesh are vital for further policy planning.

There are various Government and community-based organizations working in the field of disaster management and mitigation. The focal point of the Government of Bangladesh for disaster management is the Disaster Management Bureau (DMB), a specialized organization under the Ministry of Disaster Management and Relief. The Bangladesh Meteorological Department (BMD) is responsible for forecasting natural disasters, particularly cyclones, droughts, storms, etc. The Bangladesh Space and Remote Sensing Organization (SPARRSO) is responsible for providing satellite images to BMD, particularly as an aid to make the daily weather forecast. The Flood Forecasting and Warning Centre (FFWC) of the Bangladesh Water Development Board forecasts flood, with help from the Surface

Table 3.5.8 Summary Outline of the Key Disaster Management Bodies and their Main Function

National Disaster Management Council (NDMC)
- Establishing policies and providing overall direction for all aspects of disaster management

Defining priorities and criteria for the allocation of resources

National Disaster Management Advisory Committee (NDMAC)
- Providing advice to the NDMC, and directly to MDMR and DMB, on specific technical, management, and socio-economic aspects of disaster management, including vulnerability analysis and disaster-development links

Inter-Ministerial Disaster Management Co-ordination Committee (IMDMCC)
- Implementation of NDMC policies and decisions on an inter-ministerial basis
- Coordination of action by all government agencies and overall direction of the activities of the DMB
- Responsibility for major operational decisions during an emergency
- Decisions on allocations of relief resources though its sub-committee, the Executive Emergency Relief Management Committee

Ministry of Disaster Management and Relief (MDMR)
- Ministerial responsibility for disaster management, including the convening of the IMDMCC
- Assuring the establishment, resource management (budget), and satisfactory functioning of the DMB
- Supervision of the DRR

Disaster Management Bureau (DMB) – a part of MDMR
- Provision of expert staff services to the NDMC and IMDMCC
- Promotion of disaster prevention/mitigation and preparedness within all agencies and levels of government
- Providing guidelines, organizing training, and promoting the preparation of disaster action plans
- Providing expert services to the national Emergency Operations Centre (control room) located at MDMR at time of disaster

DIRECTORATE OF RELIEF AND REHABILITATION (DRR)
- As at present with respect to Vulnerable Group (VGD); Food for Works (FFW); Gratuitous Relief (GR) and Test Relief (TR); the management and delivery of relief supplies, and the provision of related services

DRROS AND PIOS

AS AT PRESENT UNDER THE GENERAL DIRECTION OF DRR AND THE OPERATIONAL SUPERVISION OF DC AND TNO. INCREASED ATTENTION BY DRROS IN PARTICULAR TO DISASTER PREPAREDNESS UNDER THE GUIDANCE OF THE DMB (THIS COMPENSATING FOR SOME REDUCTION IN FFW WORK)

Source: DMB, 1997

Water Modelling Centre (SWMC) and EGIS. The Department of Agriculture Extension provides different services to mitigate agricultural losses after disasters. Table 3.5.8 depicts the summary outline of the key disaster management bodies and their main function.

As the lead agency within the UN system, UNDP had a significant role in supporting the International Decade for Natural Disaster Reduction (IDNDR). The fifth UNDP Country program highlights the acute vulnerability of Bangladesh to natural disasters, and in particular the devastating impacts of disasters on the poor. The UNICEF regular program also includes many activities that contribute towards preparedness and risk reduction at the community level. UNICEF has been extensively involved in the process of preparing the training strategy that is to be implemented by the Disaster Management Bureau. The British Government (DFID) continuously supports various disaster management programs in Bangladesh. USAID-funded Flood Action Plan studies are concerned with flood response and flood proofing (FAP:14 and FAP:23), and Geographical Information Systems (FAP:19). NGOs are major contributors to relief efforts following disasters, and a number of NGOs are now developing programs for disaster preparedness and mitigation (DMB, 1998).

Bangladesh has set a pioneer example in disaster management during the cyclones of 1991 and 1997. The role of the government and non-government organizations during the pre and post-disaster periods helped shrink the number of deaths and damage. The initiatives were appreciated and recognized worldwide.

3.5.5.1 Structural Measures

The Government of Bangladesh has commenced both structural and non-structural measures for flood mitigation. With the assistance of the World Bank, a 'Flood Action Plan' with 26 components was undertaken immediately after the devastating flood of 1988.

Previously, disaster mitigation tended to be viewed as structural mitigation measures only. This concept has changed rapidly over the past few years. Structural measures for flood control like storage reservoirs, embankments of levees, channel improvements, and floodway bypasses are expensive and time consuming. The GoB gives equal importance at present to both structural and non-structural mitigation measures. It is strongly believed by the GoB that non-structural mitigation measures need to be complemented by structural mitigation measures.

As a part of structural mitigation measures the GoB with its own and external resources has so far constructed 1,841 cyclone shelters, and 200 flood shelters for evacuation of people threatened by cyclone or flood. In addition, coastal embankments about 3,931 km long have been made to protect coastal land from inundation by tidal waves and storm surges, and drainage channels of total length 4,774 km have been constructed.

A very effective cyclone warning system has been established in the country. Bangladesh Meteorological Department (BMD) has a network of four radar stations at Dhaka, Rangpur, Cox's Bazar, and Khepupara, as well as satellite ground receiving stations to receive imageries from NOAA, GMS, and InSAT to monitor cyclones as soon as they form in the Bay of Bengal. An effective communication system also exists in BMD for exchanging information both at national and international levels. SPARRSO can track cyclones every hour through the reception of imagery from GMS and NOAA satellites.

Following the devastating cyclone of 1970, the Bangladesh Red Crescent Society started the Cyclone Preparedness program (CPP) in 1972. In June 1973, the GoB approved and accepted the new program of the Red Crescent Society, and since then the Ministry of Disaster Management and Relief and the Red Crescent Society have started to operate the CPP jointly (Mohammed, 1991). CPP has a volunteer force of 27,330 trained men, and 5,466 women to disseminate cyclone information, and carry out rescue operations if a cyclone strikes the coast. Bangladesh Radio and Television at frequent intervals transmit warning messages for the events. After the devastating cyclone of 1991, the Government of Bangladesh has also established a number of multipurpose cyclone centers in the coastal areas (DMB, 1998).

The Government of Bangladesh has undertaken a Green Belt Project in the coastal areas. This is a participatory reforestation program aimed at reducing the adverse impacts of natural disasters, particularly cyclones and storm surges in the coastal regions.

3.5.5.2 Non-structural

For non-structural mitigation the GoB has emphasized on legislation, training and public awareness, institution building, and warning systems. The Disaster Management Legislation (Act) has already been designed in draft form, and is at present under the government's consideration for approval. The Act establishes a mechanism for working through State and Local Governments, and public corporations that clarifies where responsibilities lie, and provides for the formulation of a disaster management policy. A plan relating to preparedness and public awareness is an important component of the project, "Support to Comprehensive Disaster Management". Up to December 2000, the Disaster Management Bureau has conducted a total of 453 courses, workshops and seminars under the project, and about 23,000 participants have attended the programs. They include Government and Semi-Government officials of different levels, public representatives, NGO officials, local leaders, representatives of mass media, teachers, Imams (religious leaders) of mosques, and fishermen. Besides this, DMB has supported holding of disaster management training workshops in other institutes. As part of the public-awareness activities, booklets containing public information about cyclone, floods, etc., and calendars and posters with disaster information have been regularly printed and distributed at the grass-roots levels.

To raise awareness among students on various hazards and disaster management as per GoB policy, a chapter on disaster management has been included in the educational curricula from class V to XII. The GoB has also made to hold a compulsory session of at least 2 hours on disaster management in the curricula of all types of Training Institutes that train officials and non-officials.

The GoB has prioritized improving the capability of the concerned government organizations to issue early warnings, such as the Storm Warning Centre (SWC) of BMD, and Flood Forecasting and Warning Centre (FFWC) of Bangladesh Water Development Board (BWDB). As a result, there are microwave links between SWC in Dhaka to radar stations at Rangpur, Cox's Bazar and Khepupara. Under a bilateral agreement between GoB and the Government of Japan to improve warning capability, the replacement of radar in Dhaka, establishment of a new radar at Rangpur, and commissioning of a satellite ground receiving station at SWC (Dhaka) have been completed. The GoB has taken up a program to establish four seismic observatories at Chittagong (renovated the old one), Sylhet, Rangpur and Dhaka and its implementation is progressing well.

As part of the non-structural measures to cope with cyclones, the GoB is committed to improve its cyclone warning and dissemination system in all parts of the country. As part of an ongoing project support to comprehensive disaster management, initiatives have already been undertaken to review the existing warning system, and evolve simplified, easily understandable cyclone warning signals and messages that are scientific and realistic. Progress has been made to design a simple warning procedure, which is under government consideration for adaptation.

The Department of Forest, under the Ministry of Environment and Forest has undertaken a project titled "The Coastal Greenbelt Project" for the period 1995-96 to 2001-2002. The project will cover 12 coastal districts of Bangladesh such as Barisal, Jhalkati, Patuakhali, Borguna, Bhola, Bagerhat, Pirojpur, Lakshmipur, Noakhali, Feni, Chittagong, and Cox's Bazar. The main objectives of the project are to:

- Prevent loss of life and damage to property by cyclone, storms, and associated tidal surges;
- Protect and improve the coastal environment through increased vegetative cover in the project areas;
- Help poverty alleviation of the local rural population by generating supplementary income opportunities by augmenting tree cover in the coastal region;
- Contribute to the government objectives for increasing the country's forest resources;
- Help increase the stability of the coastal embankments;
- Help establish cottage industries based on forest products to be grown in plantation;
- Find multiple uses for land along the roadsides, railways, feeder roads, and embankments, rather than keeping the land fallow;
- Enrich homesteads of the coastal region with trees that produce timber, fuel-wood, and fruits; and

- Impart training to youth and elderly regarding raising nurseries and growing trees, and create awareness among people with regard to forest management that leads to income generation, and self-reliance.

The GoB and DANIDA have undertaken a project, "Consolidation and Strengthening of Flood Forecasting and Warning Services 2000-2004". The main objectives of the project are the development of flood forecast and inundation modeling for all flood-prone areas of the country; dissemination of flood forecast information and warning messages to relevant governmental institutions at the national, district, *thana*, and union levels, and to the media, NGOs and other relief organizations, and to local communities. A sustainable FFWC will be established at the end of the project.

Accurate and timely storm surge prediction is crucial for effective disaster management, and saving lives and property in the countries bordering the Bay of Bengal. This is particularly true for Bangladesh, which is the worst victim of tropical cyclones and associated storm surges. Accurate storm surge prediction is only possible by appropriate storm surge models, and through the involvement of a comprehensive storm surge prediction procedure. In view of this, a regional effort is going on in this part of the world under the sponsorship of IOC, WHO, UNESCO, and IHP. Bangladesh is closely associated with this initiative, and there has been some notable progress in giving a shape to the concept under the project titled, "Storm Surge Disaster Reduction for the Northern Part of the Indian Ocean".

For flood forecasting, a network of hydrological stations connected with telemetering gauges or by telecommunication to the Water Development Board has been established having teleprinter links with the forecasting centers. Historical records of data have been analyzed to prepare forecasting procedures. Flood forecasting in 1998 played an effective role in flood mitigation.

At present, the Disaster Management Bureau is implementing a project named, "Support to Comprehensive Disaster Management", with the financial assistance from GoB, UNDP, and UNICEF. Three basic aspects are the main focus of the project - awareness build-up at different levels of the people, enhancement of coping capabilities of common people against disaster through establishing Disaster Action Plans (DAPs), and institutionalization of the national disaster management system. An elaborate procedure has been strictly followed for the preparation of Disaster Action Plans.

The main propose of DAPs is to mobilize local communities in the most disaster prone areas to prepare and protect themselves, and to increase their own capacities to cope with and recover from disaster, without waiting for outside assistance. Initially a draft model action plan was prepared, on the basis of inputs received from 6 Zonal Disaster Preparedness Specialists (ZDPS), working at high-risk upazillas located in both cyclone and flood-prone areas of the country. While preparing the draft model the full participation of the local people and communities was ensured. The draft model was presented at a workshop in July 1998, in which a number of eminent experts of the country working on disaster management activities participated. On the basis of the expert's suggestions and recommendations, the draft model is being finalized.

Efforts are in progress for the preparation of local Disaster Action Plans for each of the 29 most disaster-prone districts, 84 upazillas, 776 unions, and 24 pourashavas. As of December 2000, the preparation of more than 600 Disaster Action Plans at union levels has been completed. The DAP basically contains three parts. The first part deals with the Union profile in language, as well as simple sketch of the hazard and vulnerability maps. The second part of the DAP contains formation of the Disaster Management Committee (DMC), and its responsibilities. The final part has all the details of the action plan, including various volunteer groups (VG) and sub-committees for the responsibilities, such as warning dissemination and precautionary response, arrangements for evacuation, arrangements for rescue and casualty care, arrangements for burial, control room, restoration of essential services, security and protection of property, damage and needs assessment, co-ordination of assistance, management of relief supplies, support to rehabilitations, logistics, training and awareness build-up, and testing and updating the plan.

The role of social capital during natural calamities cannot be ignored. Social capital is the network of

adhoc organizations created during emergency situations to respond to the needs of suffering people. It has been observed during the devastating floods of 1988 and 1998, and during the cyclone of 1991 that spontaneous, value-driven relatives, organizations, and networks rendered valuable help and assistance to the victims. In the typologies of mitigation and coping mechanisms, social capital has been identified as an important resource. BIDS undertook a study on its role after the flood of 1998.

The Disaster Management Bureau has already published a guide-book comprising Standing Orders for disaster management, which was approved by the Inter-Ministerial Disaster

Table 3.5.9 Options to Mitigate Impacts of Natural Disasters in Future

Options	Out Comes	Actors
Flood		
• Strengthening Capabilities for Flood forecasting and monitoring • Structural mitigation programs	• Real time forecast and timely possible evacuation • Mitigation of losses and sufferings • Less inundation due to embankments along the river banks	• FFWC (Flood Forecasting and Warning Centre) under Ministry of Water Resources • Surface Water Modelling Centre (SWMC) • EGIS, AFD • NGOs • Electronic media (i.e. radio, television) • MDMR (Ministry of Disaster Management and Relief) i.e. EOC, DMB and DRR
Cyclone and Storm surge		
• Strengthening of warning and forecasting centre • Shelter construction • Awareness building • Institutional arrangements up to grassroot level	• Reliable and timely forecast • Large-scale evacuation of vulnerable people • Spontaneous response to warning • Well coordination prior to and immediately after disaster	• BMD (Bangladesh Meteorological Department) • Electronic media (i.e. radio, television) • MDMR (Ministry of Disaster Management and Relief) i.e. CPP, DMB, EOC, DRR • LGED (Local Government and Engineering Department), NGOs, Donors • MOHFW (Ministry of Health, Family Planning and Welfare), AFD • DMCs (Disaster Management Centres) at national and grass-root levels • Social Organizations
Drought		
• Strengthening of National Forecasting Centre • Afforestation Programs • Re-excavation of local canals and ponds • Conservation of wetlands	• Long-range forecast for possible drought condition • Help availability of moisture in the atmosphere for precipitation and removal of dryness • Storage of water for agriculture and other purposes during drought period	• BMD (Bangladesh Meteorological Department) • MOEF (Ministry of Environment and Forest), DoF (Department of Forest) • MOWR (Ministry of Water Resources), Local Government and Engineering Department (LGED) • NGOs, Donors
Tornado		
• Improvement of observation capabilities of national meteorological service • Strengthening institutional arrangements for preparedness	• Upper air information and radar echoes leading to possible area identification • Public awareness building • Prompt rescue and relief operation with better coordination	• BMD (Bangladesh meteorological Department), SWC (Storm Warning Centre) • MDMR (Ministry of Disaster Management and Relief i.e. DMB, EDC, DRR • LGED (Local Government and Engineering Department) • MoHFP (Ministry of Health and Family Planning), AFD • NGOs
Earthquake		
• Building code (1993) compliance • Requisite number of seismic observatories • Updating the inventory of equipment to be used for rescue after earthquake • Contingency plan to cope with earthquake for each earthquake prone area • Massive awareness building program and drill	• Reduction of building vulnerability to tremor • Systematic and accurate seismic observations for future guidance and planning • Efficient and quick rescue operation to minimize casualties and after shock • Better coordination for after shock operation to lessen human sufferings • Less confusion, casualties and injuries	• BMD, GSB • AFD • MDMR (DMB, EOC, DRR) • MoHA (CDdFB) • DAs, MC • MoHFW • NGOs, Donors • Social Organizations

Source: SoE Study Team

Management Coordination Committee (IMDMCC). The orders provided in the guide-book replace the standing orders for the flood published in 1984, and for the cyclone in 1985. Though these orders are specially made for cyclones and floods, they can be used for any type of disaster. While preparing the guide-book existing orders and responsibilities of relevant ministries, agencies, armed forces, administration units at Zilla, Upazilla, and Union levels, and disaster management committees were considered, and taken into account. This book emphasizes the coordination and cooperation between different NGOs, voluntary organizations, and relevant Government and non-government institutions (DMB, 1997).

3.5.6 SUGGESTED OPTIONS AS FUTURE MEASURES

Brief descriptions of future needs, along with potential local stakeholders responsible to undertake the measures are presented in Table 3.5.9.

3.5.7 CONCLUSION

Pre-disaster

The mechanisms to sustain institutional networking should be enhanced, and funds to sustain such programs need to be ensured. The sources of such funds can be from the donors, or can be collected from tax imposed for the sales and purchase of lands, revenue collected from auctions from *haat, bazaars,* and *jalmahals,* and also by the revival of the 5 per cent ADP reserved for disaster management fund. Door-to-door awareness campaigns can enhance the capacity building activities of communities. Proper pre-disaster preparedness programs should be further enhanced to empower the community on the matter. A mechanism should be in place to repair and maintain cyclone shelters regularly, so that during the disasters people can use them right away. There is lack in the communication system from the grassroots level up to the ministerial level, which should be filled through a proper system. The coordinated efforts of government and non-government agencies are essential for every type of disaster mitigation. DMB has already submitted a DM Legislation and Plan to the government, which should be approved, and properly implemented. Anticipatory research on forecasting natural disasters specific to Bangladesh should be encouraged. The National Building Code 1993, and micro zoning should be enforced in the urban development system to reduce fatal impacts of earthquakes. Re-excavations of the water bodies in rural areas are essential. Continuous drill practices, and exercises on mock disaster management will help volunteers be prepared for any immediate action.

Post Disaster

Capacity-building activities of various institutions and agencies for implementation of relief and rehabilitation programs should be strengthened. The capacity building for grassroots and national level monitoring needs to be enhanced. Evaluations should be done through postmortem analysis of disaster management after every disaster, which will act as a learning guide for future. Case studies on major man-made disasters should be taken up, and put on record for future guidance towards avoiding such events. Continuous research on modern innovative coping and mitigation measures to reduce the devastating impacts of all kinds of natural disasters should be encouraged.

List of some severe Natural Disasters affecting Bangladesh are presented in the following Annexure, which depicts the time, magnitude of damages and other impacts of various types of natural disasters on human life.

Reference

Ahmad, Q.K. (ed) (2000). *Bangladesh Water Vision: Towards a Sustainable Water World.* Bangladesh Water Partnership. Dhaka, Bangladesh.

Ali, A. (2000). Vulnerability of Bangladesh to Climate Change and Sea Level Rise, Paper Presented in the *International Day for Disaster Reduction Seminar,* 11 October 2000, Dhaka, Bangladesh.

Asian Development Bank, (1991). *Disaster Mitigation in Asia and the Pacific.* ADB. Manila, Philippines.

Carter, W. Nick (1991). *Disaster Management: A Disaster Manager's Handbook.* Asian Development Bank. Manila, Philippines.

Chowdhury, M.H.K. and A. Hussain, (1981). Aridity and Drought Conditions of Bangladesh. Tropical Droughts (Meteorological Aspects and Implications for Agriculture). Journal of WMO Program on Research in *Tropical Meteorology,* pp 73-80. New Delhi, India.

Disaster Management Bureau (1997). *Duryog Bishoyok Adeshabali,* Ministry of Disaster Management and Relief. Government of People's Republic of Bangladesh.

Disaster Management Bureau (1998). *An Introduction to Disaster Management in Bangladesh and the Disaster Management Bureau: Coordination-Facilitation-Information-Training).* Ministry of Disaster Management and Relief. Government of People's Republic of Bangladesh.

Encyclopedia Britannica (1980). *William Benton.* The University of Chicago, USA.

Hamid, M. A. (1991). *A Data Base on Agriculture and Foodgrains in Bangladesh (1947-48 to 1989-90).* Dhaka, Bangladesh.

Huq, S., Rahman, A..A., Haider, R. (1991). *Cyclone '91: An Environmental and Perceptional Study.* Bangladesh Centre for Advanced Studies (BCAS), Dhaka, Bangladesh.

Huq, S. (ed) (1999). *Vulnerability and Adaptation to Climate Change for Bangladesh.* Kluwer Academic Publishers, Netherlands.

Iqbal, A. (2000). Personal communication on the ensuing publication on Drought in Bangladesh Agriculture.

Milliman, J.D., Broadus, J.M. and Frank G. (1989). Environmental and Economic Impact of Rising Sea Level and Subsiding Deltas: The Nile and Bengal Examples. In *Bangladesh Quest. Vol.: 1,* pp 11-12.

Karmakar, S. (1989). Natural Disasters in Bangladesh: A Statistical Review. Paper presented at the Seminar on *Impact of Information towards Mitigation of Natural Disasters,* held on January 7-8, 1989 at BANSDOC. Dhaka, Bangladesh.

Mohammed, H. (1999). Cyclone Preparedness Program (CPP): A Success Story of Bangladesh Paper Presented at *IDNDR Program Forum.* 6 July 1999.

Pramanik, M.A.H. (1991). *Natural Disasters*. Article prepared for Bangladesh Space Research and Remote Sensing Organization (SPARRSO). Dhaka, Bangladesh.

Rahman, A.A., Saleemul Huq, Raana Haider, Eirik G. Jansen (1994). *Environment and Development in Bangladesh.* The University Press Limited. Dhaka, Bangladesh.

Rashid, Harun and Pramanik, M.A.H. (1990). *Visual Interpretation of Satellite Imagery for Monitoring Floods in Bangladesh.* Springer-Verlag New York Inc. U.S.A.

Rashid, H. (1991). *Geography of Bangladesh.* The University Press Limited. Dhaka, Bangladesh.

Walker, B., and Steffen, W. (1997). *An Overview of the Implications of Global Change for Natural and Managed Terrestrial Ecosystems.* Conservation Ecology (online). Available from the Internet. URL:http://www.consecol.org/vol1/iss2/art2

Annexure

List of Some Severe Natural Disasters Affecting Bangladesh

Types of Disaster	Subset of Disaster	Year	Month	Day	Persons Killed	Persons Injured	Home-less	Affected	Total Affected	Damage in US$('000s)
Wind storm	Cyclone	1970	11	12	300000	n.a.	n.a.	3648000	400000	86400
Wind storm	Cyclone	1971	5	8	163	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Tornado	1972	4	2	200	n.a.	n.a.	25000	25000	n.a.
Flood	Flood	1972	6	25	50	n.a.	n.a.	n.a.	n.a.	n.a.
Flood	Flood	1973	3	n.a.	427	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Storm	1973	4	9	700	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Storm	1973	4	12	200	15000	10000	25000	50000	n.a.
Flood	Flood	1973	8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Cyclone	1973	12	9	1000	n.a.	n.a.	n.a.	n.a.	n.a.
Flood	Flood	1974	7	n.a.	28700	n.a.	2000000	36000000	38000000	579200
Wind storm	Cyclone	1974	8	15	2500	n.a.	n.a.	n.a.	n.a.	n.a.
Drought	Drought	1974	10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Cyclon	1974	11	28	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Storm	1974	3	n.a.	300	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Tornado	1976	4	10	46	200	n.a.	n.a.	200	n.a.
Wind storm	Tornado	1976	5	9	1	n.a.	n.a.	n.a.	n.a.	201
Flood	Flood	1976	6	15	103	n.a.	n.a.	4000000	4000000	n.a.
Wind storm	Storm	1977	4	1	600	n.a.	n.a.	10000	10000	50000
Wind storm	Cyclone	1977	4	24	13	100	n.a.	n.a.	100	n.a.
Flood	Flood	1977	9	n.a.	5	n.a.	n.a.	200000	200000	n.a.
Flood	Flood	1977	10	6	21	500	n.a.	n.a.	500	n.a.
Flood	Flood	1977	10	13	8	n.a.	n.a.	13650	13650	n.a.
Wind storm	Storm	1978	4	9	1000	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Storm	1978	5	5	30	100	n.a.	n.a.	100	n.a.
Flood	Flood	1978	8	n.a.	17	n.a.	n.a.	400000	400000	n.a.
Wind storm	Cyclone	1979	5	2	3	150	n.a.	n.a.	150	n.a.
Drought	Drought	1979	6	n.a.	18	n.a.	n.a.	2000	2000	n.a.
Wind storm	Cyclone	1979	8	17	50	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Cyclone	1980	4	n.a.	11	50	n.a.	1000	1050	n.a.
Flood	Flood	1980	8	n.a.	655	n.a.	n.a.	10000000	10000000	150000
Flood	Flood	1980	9	n.a.	0	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Tornado	1981	4	15	70	12000	n.a.	n.a.	12000	n.a.
Wind storm	Cyclone	1981	3	6	15	n.a.	25000	n.a.	25000	n.a.
Wind storm	Cyclone	1981	12	10	1000	n.a.	n.a.	2000000	2000000	n.a.

Types of Disaster	Subset of Disaster	Year	Month	Day	Persons Killed	Persons Injured	Homeless	Affected	Total Affected	Damage in US$('000s)
Flood	Flood	1982	9	7	0	n.a.	25000	283000	308000	n.a.
Wind storm	Cyclone	1983	3	21	6	150	n.a.	n.a.	150	n.a.
Flood	Flood	1983	4	n.a.	78	n.a.	n.a.	60000	60000	n.a.
Wind storm	Tornado	1983	4	26	12	200	n.a.	n.a.	200	n.a.
Drought	Drought	1983	7	5	n.a.	n.a.	n.a.	20000000	20000000	n.a.
Flood	Flood	1983	7	n.a.	12	n.a.	100000	4000000	4100000	n.a.
Flood	Flood	1983	8	n.a.	41	n.a.	n.a.	n.a.	n.a.	n.a.
Flood	Flood	1983	9	n.a.	114	n.a.	n.a.	3000000	3000000	n.a.
Wind storm	Cyclone	1983	10	15	600	n.a.	n.a.	5000	5000	n.a.
Wind storm	Cyclone	1983	11	13	67	n.a.	n.a.	n.a.	n.a.	n.a.
Flood	Flood	1984	5	n.a.	1200	n.a.	n.a.	30000000	30000000	n.a.
Flood	Flood	1984	6	25	0	n.a.	n.a.	n.a.	n.a.	n.a.
Earth-quake	Earthquake	1984	12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Storm	1985	3	28	50	n.a.	n.a.	18000	18000	n.a.
Wind storm	Cyclone	1985	5	25	10000	n.a.	510000	1300000	1810000	n.a.
Flood	Flood	1985	6	4	300	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Cyclone	1985	7	5	27	n.a.	n.a.	400000	400000	n.a.
Wind storm	Storm	1985	10	16	71	300	n.a.	1000	1300	n.a.
Extreme tempera-ture	Cold wave	1985	12	n.a.	0	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Storm	1986	3	n.a.	19	n.a.	10000	n.a.	10000	n.a.
Wind storm	Storm	1986	4	4	100	3000	10000	n.a.	13000	n.a.
Flood	Flood	1986	8	2	4	n.a.	n.a.	100000	100000	n.a.
Flood	Flood	1986	8	7	26	n.a.	60000	n.a.	60000	n.a.
Wind storm	Tropical storm	1986	9	26	40	n.a.	100000	2600000	2700000	n.a.
Wind storm	Cyclone	1986	11	9	25	100	n.a.	n.a.	100	n.a.
Wind storm	Cyclone	1987	6	4	12	n.a.	n.a.	n.a.	n.a.	n.a.
Flood	Flood	1987	6	10	1000	n.a.	n.a.	3000000	3000000	2000
Flood	Flood	1987	7	22	2055	n.a.	n.a.	29700000	29700000	330000
Flood	Flood	1987	8	n.a.	625	n.a.	n.a.	n.a.	n.a.	727500
Earth-quake	Earthquake	1988	2	6	2	100	n.a.	n.a.	100	n.a.
Wind storm	Storm	1988	5	23	28	n.a.	n.a.	n.a.	n.a.	n.a.
Wind-storm	Storm	1988	6	13	5	200	n.a.	5000	5200	n.a.
Slide	Landslide	1988	7	n.a.	200	n.a.	n.a.	n.a.	n.a.	n.a.
Flood	Flood	1988	8	n.a.	2379	n.a.	28000000	45000000	73000000	2137000
Wind storm	Storm	1988	10	19	31	n.a.	n.a.	n.a.	n.a.	n.a.
Wind-storm	Cyclone	1988	11	29	1000	n.a.	2000000	8568860	10568860	n.a.
Extreme tempera-ture	Cold wave	1989	1	n.a.	70	n.a.	n.a.	n.a.	n.a.	n.a.

Types of Disaster	Subset of Disaster	Year	Month	Day	Persons Killed	Persons Injured	Home-less	Affected	Total Affected	Damage in US$('000s)
Draught	Draught	1989	4	n.a.	0	n.a.	n.a.	5000000	5000000	n.a.
Wind storm	Cyclone	1989	4	26	800	2000	n.a.	100000	102000	16200
Wind storm	Cyclone	1989	5	26	15	2000	n.a.	n.a.	2000	n.a.
Flood	Flood	1989	8	14	180	n.a.	n.a.	200000	200000	n.a.
Extreme tempera-ture	Cold wave	1989	12	n.a.	100	n.a.	n.a.	n.a.	n.a.	n.a.
Flood	Flood	1990	3	25	166	1600	n.a.	10000	11600	n.a.
Wind storm	Tornado	1990	4	n.a.	76	200	n.a.	n.a.	200	n.a.
Wind storm	Tornado	1990	5	2	19	500	4000	0	4500	n.a.
Flood	Flood	1990	7	n.a.	65	n.a.	n.a.	2000000	2000000	n.a.
Wind storm	Cyclone	1990	10	8	370	n.a.	n.a.	13870	13870	n.a.
Wind storm	Storm	1990	12	21	250	n.a.	n.a.	n.a.	0	n.a.
Extreme tempera-ture	Cold wave	1990	12	29	67	n.a.	n.a.	n.a.	0	n.a.
Wind-storm	Cyclone	1991	4	29	138866	1390540	300000	15000000	15438849	1780000
Wind-storm	Tornado	1991	5	7	121	300	n.a.	n.a.	300	n.a.
Flood	Flood	1991	5	n.a.	200	0	0	1200000	1200000	n.a
Flood	Flood	1991	7	n.a.	n.a.	0	0	1590000	1590000	n.a
Flood	Flood	1991	9	10	100	0	200000	1000000	1200000	150000
Extreme tempera-ture	Cold wave	1991	12	24	182	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Storm	1992	1	31	7	200	0	0	1200000	1200000
Flood	Flood	1992	4	18	15	200	n.a.	n.a.	200	n.a.
Wind storm	Storm	1992	4	22	16	100	n.a.	n.a.	100	n.a.
Flood	Flood	1992	6	22	0	n.a.	45000	n.a.	45000	n.a.
Flood	Flood	1992	7	11	0	n.a.	30000	n.a.	30000	n.a.
Wind storm	Cyclone	1993	1	9	50	500	2000	n.a.	2500	n.a.
Wind storm	Storm	1993	1	12	31	2000	n.a.	750000	752000	n.a.
Wind storm	Storm	1993	2	19	8	500	70000	n.a.	70500	n.a.
Wind storm	Storm	1993	3	27	300	200	25000	n.a.	25200	n.a.
Wind storm	Storm	1993	5	7	9	250	3000	n.a.	3250	n.a.
Wind storm	Storm	1993	5	9	15	70	n.a.	n.a.	70	n.a.
Wind storm	Cyclone	1993	5	13	14	n.a.	n.a.	7500	7500	n.a.
Wind storm	Storm	1993	5	17	25	2000	5000	n.a.	7000	n.a.
Flood	Flood	1993	6	n.a.	28	0	0	3207056	3207056	n.a.
Flood	Flood	1993	7	n.a.	162	0	0	11469537	11469537	n.a.
Flood	Flood	1993	8	21	4	20	75000	1000000	1075020	n.a.
Extreme tempera-ture	Cold wave	1994	2	n.a.	29	n.a.	n.a.	n.a.	n.a.	n.a.

Types of Disaster	Subset of Disaster	Year	Month	Day	Persons Killed	Persons Injured	Home-less	Affected	Total Affected	Damage in US$('000s)
Wind storm	Cyclone	1994	3	28	40	150	n.a.	n.a.	150	n.a.
Wind storm	Storm	1994	4	2	20	200	5000	0	5200	n.a.
Flood	Flood	1994	4	19	61	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Cyclone	1994	5	2	130	3559	200000	450000	653559	125000
Wind storm	Storm	1994	5	18	15	100	n.a.	n.a.	100	n.a.
Flood	Flood	1994	5	19	12	0	0	100	100	n.a.
Flood	Flood	1994	6	3	3	n.a.	n.a.	25000	25000	n.a.
Flood	Flood	1994	8	19	40	n.a.	70000	300000	370000	n.a.
Extreme tempera-ture	Cold wave	1995	1	n.a.	120	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Storm	1995	4	12	69	1500	50000	0	51500	n.a.
Wind storm	Tornado	1995	4	12	6	70	2500	0	2570	n.a.
Flood	Flood	1995	5	15	50	n.a.	110000	351325	461325	n.a.
Wind storm	Storm	1995	5	15	525	n.a.	70000	2000000	2070000	n.a.
Flood	Flood	1995	6	15	250	n.a.	n.a.	12656006	12656006	n.a.
Flood	Flood	1995	9	n.a.	400	n.a.	400000	7600000	8000000	n.a.
Wind storm	Cyclone	1995	11	25	172	n.a.	n.a.	250000	250000	n.a.
Extreme tempera-ture	Cold wave	1996	1	23	200	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Storm	1996	4	23	17	300	n.a.	n.a.	300	n.a.
Wind storm	Storm	1996	5	8	140	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Storm	1996	5	13	525	35691	0	82600	118291	n.a.
Flood	Flood	1996	7	n.a.	33	n.a.	500000	5663319	6163319	n.a.
Wind storm	Storm	1996	7	27	60	n.a.	n.a.	n.a.	n.a.	n.a.
Flood	Flood	1996	9	2	22	n.a.	n.a.	165000	165000	n.a.
Wind storm	Cyclone	1996	10	29	24	100	n.a.	n.a.	100	n.a.
Extreme tempera-ture	Cold wave	1997	1	21	33	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Storm	1997	3	23	11	101	n.a.	n.a.	101	n.a.
Wind storm	Cyclone	1997	5	18	111	10000	1000000	2042738	3052738	n.a.
Flood	Flood	1997	7	13	79	30	100000	800000	900030	n.a.
Wind storm	Storm	1997	8	27	100	n.a.	n.a.	n.a.	n.a.	n.a.
Wind storm	Cyclone	1997	9	27	188	1529	0	750000	751529	n.a.
Wind storm	Tornado	1997	10	12	15	500	n.a.	n.a.	500	n.a.
Earth-quake	Earthquake	1997	11	22	21	200	n.a.	n.a.	200	n.a.
Extreme tempera-ture	Cold wave	1998	1	9	120	n.a.	n.a.	34000	34000	n.a.

Types of Disaster	Subset of Disaster	Year	Month	Day	Persons Killed	Persons Injured	Homeless	Affected	Total Affected	Damage in US$('000s)
Wind storm	Storm	1998	3	23	28	100	n.a.	n.a.	100	n.a.
Wind storm	Storm	1998	4	23	14	200	n.a.	n.a.	200	n.a.
Flood	Flood	1998	5	20	19	504	n.a.	108440	108944	n.a.
Wind storm	Storm	1998	7	3	60	n.a.	n.a.	n.a.	n.a.	n.a.
Flood	Flood	1998	7	8	918	50	n.a.	15000000	15000050	3000000
Wind storm	Storm	1998	11	25	200	n.a.	n.a.	121000	121000	n.a.
Wind storm	Tornado	1999	3	26	2	60	100000	n.a.	100060	n.a.
Wind storm	Storm	1999	4	7	7	200	0	0	200	n.a.
Wind storm	Storm	1999	4	10	66	100	0	0	100	n.a.
Wind storm	Storm	1999	5	7	3	150	0	1000	1150	n.a.
Flood	Flood	1999	7	n.a.	31	20	20000	421250	4412270	n.a.
Earth-quake	Earthquake	1999	7	22	6	200	15000	0	15200	n.a.
Flood	Flood	1999	8	15	17	50	0	0	50	n.a.

Source : Disaster Preparedness Centre, AIT, Bangkok

4.1 CONCLUSIONS AND RECOMMENDATIONS

The degradation of the natural resource base and environment in Bangladesh started with various human and economic development activities, before adequate mitigation measures were considered an integral part of the development process. This happened due to a lack of appropriate sector policies, awareness, and integration of environment and development into conventional development strategies. In the conventional paradigm to attain economic growth the concept of "grow first and clean later" was the underlying principle. In the last decade, particularly after the Rio Summit in 1992, it has been realized worldwide that sustainable development cannot be achieved without environmental conservation. The government of Bangladesh has now realized the need for concern regarding environmental issues, and started incorporating environment into policies dealing with various sectors. However, the major thrust of government policy remains towards poverty alleviation through employment generation and economic growth, and little has been achieved in integrating environmental protection.

The key environmental concerns of the country that have been identified are land degradation, water pollution and scarcity, urban air pollution, loss of biodiversity, and impacts of natural disasters on economy and livelihood systems. There are sectoral polices to address these issues, but a lack of integration and overlapping of responsibilities prevails among the agencies. There is a lack of coherence among policies, and no holistic approach to mitigate environmental degradation and conserve resources. However, this can be resolved through inter-ministerial decision and coordination. Various policies are now under preparation by the relevant ministries that aim for a sustainable approach towards environmental management and development.

The major gaps that have been identified in mitigating pressures on the natural resource base are mostly related to the lack of institutional capability, lack of proper data and research, particularly on impact assessment, and inadequate action programs for policy implementation. The impacts of climate change on the natural ecosystem, livelihood system, and sustainable development are of future concern. Therefore, it is important to develop a climate change adaptation strategy for the country, particularly to mitigate impacts of extreme climatic events such as droughts, floods, cyclones, and storm surges. This policy also has to be integrated with the existing sectoral policies.

4.1.1 Policy and Policy Integration

The following policy and policy-level integration needs to be pursued to promote sustainable development in the country, as well as improve environment and quality of life as an integral part of the process.

Policy and Policy Level Integration	Process and Requirements	Actors and Participants
Land use Policy	❖ A consultative process is required for integrating sectoral policies and bringing coherence among the policies ❖ Resources are required for integrating sectoral policies and developing a comprehensive land use policy	❖ Ministry of Environment and Forest can take coordination role for integrating sectoral polices, in association with Ministry of Land ❖ Ministry of Water Resources, Ministry of Agriculture, Ministry of Industry, and Ministry of Trade and Commerce will be the other major participants in this exercise ❖ Non-government research and policy institutes, academicians, and participation of civil service organizations will make it more acceptable to society
Integrating Environment and Climate Change into Sectoral Policies	❖ A consultative process is required for integrating environment and climate change issues into sectoral policies ❖ Resources are required for integrating these issues into the sectoral policies	❖ Department of Environment under the Ministry of Environment and Forest can take the lead in integrating environment and climate change issues into sectoral polices. Climate change issue is already incorporated in the National Water Policy, which could be used as an example for other sectoral policies ❖ Non-government research and policy institutes, academicians, and participation of civil service organizations will make it more acceptable to society

4.1.2 Institutional Capacity Building

Lack of institutional capability has been identified as a major constraint in implementing policy, and enforcing environmental acts and regulations. In order to enhance performance of the Department of Environment regarding the latter, institutional capacity building in terms of equipment, training, and additional financial support is essential. In addition, promoting a strong network among researchers and policy makers will enable quality research, and sharing of knowledge and experiences towards better implementation of policies.

various impacts of degradation of land and water ecosystems on human health, livelihood systems, and sustainable development of the country.

Policy integration, institutional capacity building, developing options for mitigating environmental degradation, and action programs all require adequate international assistance, both financial and technical.

The State of Environment report is strongly recommending inclusion of environmental issues in various sector policies in Bangladesh, and

Type of Capacity Building	Recipient and Resource Requirement	Outcome
Improvement of Analytical Laboratories, Monitoring Equipment, and Training	❖ Department of Environment under Ministry of Environment and Forest ❖ Resources are required for improving analytical laboratories and training	❖ Improve analytical capabilities, which will enable DoE to produce good quality data ❖ Better Enforcement of Environmental Act and Regulations
Networking and Dissemination of Information	❖ Department of Environment will establish a network of professionals, including researchers from government and private sector ❖ Resources are required for maintaining this professional network	❖ Sharing of knowledge and experiences among professional groups ❖ Assistance in formulating action research and policy advocacy
Waste Reception and Treatment Facilities at Ports	❖ Ministry of Shipping and Port Authority ❖ Resources are required for installing reception and treatment facility	❖ Reduce pollution load in the coastal and marine areas

4.1.3 Action Program and Research

The ultimate success of any policy or decision depends on the extent to which it turns into action programs and research efforts to bridge gaps. It is now well recognized in Bangladesh that the acts, laws, and regulations to diminish environmental degradation are not inadequate, but rather their enforcement through different programs is weak. Action and research programs are required to mitigate environmental degradation and restore the degraded environment. A number of appropriate programs have been identified in the previous chapter. These action programs and research activities should be undertaken immediately, to prevent further deterioration of the environmental resource base, and to assess the

making the different sector policies coherent regarding environment. These aspects are lacking in the existing policy measures and action programs. For example, water resources need to be managed both qualitatively and quantitatively due to their importance to economic development, and the physical and social environments. Frequent floods and droughts pose tremendous threats to rural livelihoods and the national economy. The recognition of inter dependency among sub-sectors and different ministries, with comprehensive, integrated planning can address the interests of all users, as well as reduce the conflicts in the system. This will enable the country to progress towards a sustainable environment and development.

Type of Actions and Programs	Outcome	Actors and Resource Requirement
Land Degradation		
Promote balanced use of chemical fertilizers and adoption of IPNS	❖ Improvement of soil quality, increased crop production, and prevention of further land degradation	❖ Ministry of Agriculture, along with their different wings (BARC, NARS, DAE, etc.) ❖ *Resources are required to carry out promotional activities and awareness raising*
Adjustment of cropping patterns on a large scale incorporating legume/green manure crops, and crop diversification	❖ Improvement of organic content of soil, and enabling sustainable agricultural production	❖ Ministry of Agriculture, along with their different wings (BARC, NARS, DAE, etc.) ❖ *Resources are required for research and implementation*
Water Pollution and Scarcity		
Clean-up and Rehabilitation of Pollution Hot-spots: Dhaka, Chittagong, and Khulna	❖ Improvement of water quality for different uses, and restoration of habitat for aquatic species	❖ Ministry of Environment and Forest, Ministry of Industry, Ministry of Water Resources, Civil Society, and Media ❖ *Resources are required for reducing pollution load and augmentation of dry season water flow*
Air Pollution		
Use of Low Smoke Lube Oil for Two-stroke Engined Vehicles	❖ Reduction by half of pollution load	❖ Department of Environment, in association with Ministry of Energy and Mineral Resources ❖ *Resources are necessary for awareness campaigns*
Traffic Management	❖ Reduction of pollution load	❖ City Corporation ❖ *Resources are essential for Traffic Management*
Biodiversity		
Conservation Program for Ecologically Critical Areas	❖ Conservation of biodiversity	❖ Department of Environment and Forest, in association with UNDP and other relevant institutes ❖ *Resources are essential to carry out conservation programs*
Natural Disaster		
Real-time forecasting and preparedness for natural disasters	❖ Reduction in loss of life and property	❖ Disaster Management Bureau, in association with SWMC and EGIS II

Acronyms and Abbreviations

ADB	Asian Development Bank
APM	Ambient Particulate Matter
BADC	Bangladesh Agricultural Development Corporation
BAEC	Bangladesh Atomic Energy Commission
BARC	Bangladesh Agricultural Research Coubcil
BBS	Bangladesh Bureau of Statistics
BCAS	Bangladesh Centre for Advanced Studies
BCSIR	Bangladesh Council of Scientific and Industrial Research
BECA	Bangladesh Environment Conservation Act
BELA	Bangladesh Environment Lawyers Association
BFD	Bangladesh Forest Department
BFIDC	Bangladesh Forest Industry Development Corporation
BGS	British Geological Survey
BIWTA	Bangladesh Inland Water Transport Authority
BMD	Bangladesh Meteorological Department
BMDA	Barind Multipurpose Development Authority
BNBG	Bangladesh National Biodiversity Group
BNH	Bangladesh National Herbarium
BOD	Biochemical Oxygen Demand
BRAC	Bangladesh Rural Advancement Committee
BRTA	Bangladesh Road Transport Authority
BSCIC	Bangladesh Small and Cottage Industries Corporation
BWDB	Bangladesh Water Development Board
CARDINA	Coastal Area Resource Development and Management Association
CARE	Co-operative Assistance of Relief Everywhere
CBD	Conservation of Biological Diversity
CEN	Coalition of Environmental NGOs
CHT	Chittagong Hill Tracts
CIDA	Canadian International Development Agency
CITES	Convension on International Trade of Wild Fauna and Flora
CNG	Compressed Natural Gas
CO_2	Carbon dioxide g
COD	Chemical Oxygen Demand
CPP	Cyclone Preparedness Program
CUS	Centre for Urban Studies
DAE	Department of Agricultural Extension
DANIDA	The Danish International Development Agency
DAP	Disaster Action Plan
DB	Decibel
DFID	Department for International Development
DHV	Consultant Group; The Netherlands
dl	Deciliter
DMB	Disaster Management Bureau
DMC	Disaster Management Committee
DO	Dissolved Oxygen
DoE	Department of Environment
DoFL	Department of Fisheries and Livestock
DPHE	Department of Public Health Engineering
dS/m	Decisimen per Meter
DTWs	Deep Tube Wells
EC	Electric Conductivity
ECA	Environmental Conservation Acts
ECAM	Ecologically Critical Area Management
ECAs	Ecologically Critical Areas
ECNWRC	Executive Committee of National Water Resources Council
ECR	Environmental Conservation Regulation
EEA	European Environment Agency
EGIS	Environment and GIS Support for Water Sector Planning
EIA	Environmental Impact Assessment
EMP	Environment Management Plan
ENSO	El-Nino Southern Oscillation
EPC	Environmental Pollution Control Ordinance
EPWTA	East Pakistan Water and Power Transport Authority
EU	European Union
FAO	Food and Agricultural Organization
FAP	Flood Action Plan
FCD	Flood Control and Drainage
FCDI	Flood Control Drainage and Irrigation
FD	Forest Department
FFWC	Flood Forecasting and Warming Centre
FFYP	Five Fifth Year Plan
FPCO	Flood Plan Coordination Organization

FRI	Forest Research Institute
GBM	The Ganges-Brahmaputra-Meghna
GEF	Global Environmental Facility
GEMS	Global Environmental Monitoring System
GMS	Geostatic Meteorologic Station
GNP	Gross National Product
GoB	Government of Bangladesh
GWT	Ganges Water Treaty
HYV	High Yield Variety
IAEA	International Atomic Energy Agency
ICLARM	International Centre for Living Aquatic Resources Management
ICZM	Integrated Coastal Zone Management
IDNDR	International Decade for Natural Disaster Reduction
IEE	Initial Environmental Examination
IFAD	International Fund for Agricultural Development
IMDMCC	Inter-Ministerial Disaster Management Coordination Committee
IPM	Integrated Pest Management
IPNS	Integrated Plant Nutrient System
ITCZ	Inter-Tropical-Conservation-Zone
IUCN	International Union for the Conservation of Nature
KOE	Kilogram Oil Equivalent
LGED	Local Government Engineering Department
MACH	Management of Aquatic Resources Management through Community Husbandry
MAF	Million-Acre Feet
MARPOL	Marine Pollution Convention
MEMR	Ministry of Energy and Mineral Resources
MES	Meghna Estuary Study
MoEF	Ministry of Environment and Forest
MoL	Ministry of Land
MP	Murate of Phosphate
NC	North Central
NCA	Net Cultivable Area
NCS	National Conservation Strategies
NE	North East
NEMAP	National Environment Management Action Plan
NGOs	Non Government Organizations
NIPSOM	National Institute of Preventive and Social Medicine
NLUP	National Land Use Policy
NMIDP	National Minor Irrigation Development Project
NOAA	National Oceanographic and Atmospheric Administration
NORAD	Norwegian Agency for Development and Cooperation
NW	North West
NWMP	National Water Management Plan
NWP	National Water Plan
NWRC	National Water Resources Council
NWRD	National Water Resource Database
OECD	Organization for Economic Co-Operation and Development
PKI	Potential Key Issues
PRIF	Pre-investment Feasibility
PSIR	Pressure, State, Impact and Response
REIS	Riverbank Erosion Impact Study
RF	Reserved Forests
SEMP	Sustainable Environment Management Program
SLR	Sea Level Rise
SPARRSO	Space Research and Remote Sensing Organization
SPM	Suspended Particulate Compounds
SRDI	Soil Resources Development Institute
SRF	Sundarbans Reserved Forest
SS	Suspended Solids
STWs	Shallow Tube Wells
SW	South West
SWMC	Surface Water Modelling Centre
TSP	Triple Super Phosphate
TSS	Total Suspended Solids
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNESCO	United Nations Education, Science and Cultural Organization
USAID	United States Assistance for International Development
USEPA	United State Environment Projection Agency
USF	Unclassed State Forest
VG	Volunteer Groups
VOC	Volatile Organic Compounds
WARPO	Water Resource Planning Organization
WASA	Water Supply Authority
WB	The World Bank
WHO	World Health Organization
WQS	Water Quality Standard
ZDPS	Zonal Disaster Preparedness Specialists

COMPONENTS OF THE REPORT

The Bangladesh State of Environment report has been prepared based on the format provided by UNEP, and is composed of four parts. The components of the report are as follows

Chapter One: Executive Summary which depicts the status of the key environmental issues of the country (7 pages)

Chapter Two: Overview of Major Environmental Development and Trends which provides broad description about natural and ecological resource base of the country, and major environmental concerns in the development context (15 pages)

Chapter Three: Key Issues, which describes pressures, state, impacts and responses regarding land degradation, water pollution and scarcity, air pollution, biodiversity and natural disasters according to a Pressure-State-Impact-Response (P-S-I-R) analytical framework. It also attempts to identify gaps, and future options towards attaining sustainable development by enhancing the environmental resource base (92 pages)

Chapter Four: Conclusion and recommendations provides possible immediate actions in the arenas of policy, research, and action to combat with the situation towards sustainable environmental management and development (3 pages)

Appendices: In addition to the above mentioned chapters, there are five appendixes are in this report. Appendix-1 provides acronyms and abbreviations, appendix-2 provides components of the report, appendix-3 provides list of participants attended in the national training workshop, appendix-4 provides list of participants attended in the first national consultation on draft state of environment report, and appendix-5 provides list of contributors.