Environment Cost for Climate Change

June 2009

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June 2009

Climate Change Cell
Department of Environment

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Foreword

The impacts of global warming and climate change are worldwide. For Bangladesh they are most critical because of its geographical location, high population density, high levels of poverty, and the reliance of many livelihoods on climate-sensitive sectors, such as agriculture, fisheries.

To address current impacts and manage future risks of climate change and variability towards development of a climate resilient Bangladesh, the government has established the Climate Change Cell (CCC) in the Department of Environment (DoE) under the Comprehensive Disaster Management Programme (CDMP). Climate change research, covering modeling and adaptation is one of the major activities of the Cell.

CCC in association with its Technical Advisory Group (TAG) and other stakeholders identified a set of research activities related to climate change in Bangladesh through a number of consultations. The activities have been prioritized and a number of projects have been commissioned in last few years.

Climate change impacts can undermine countries' efforts to achieve the goal of sustainable development, especially the Least Developed Countries like Bangladesh. Sustainable development depends on economic growth, social justice, and environmental integrity. It is hard to estimate the market value of impacts of climate change (and variability) on environmental integrity. However, these needs to be monetized to the best possible way to bring policy makers and planners on board. It will provide them with an instrument that enables in interpreting economical, social and environmental cost while planning development program.

Environmental resources are different in nature and types, so no single theory and method is applicable for valuation of the environment. In developing countries like Bangladesh, it is very difficult to make the environmental valuation perfectly because of data constraints, lack of appropriate modeling tools & techniques and technical expertise. But experience and real life scenario shows that it is worth learning to begin with something.

The study focused on economic impact of climate change on agriculture including land degradation and impact under different Sea Level Rise (SLR) scenario. This refers to costing of events related to climate change such as cost for floods 1998, 2004 & 2007 and Sidr 2007. Focus was on the agriculture sector which includes crop, livestock, fisheries, biodiversity loss etc.

It is expected that the research will open a window to dive deeper into the issues of environment cost of climate change. This study will encourage researchers and practitioners to undertake more integrated approach towards assessing environment cost of impacts of climate change. That will facilitate policy makers and planners to formulate viable adaptation policies/strategies and action plan.

Zafar Ahmed Khan, PhD
Director General
Department of Environment

Acronyms and Abbreviations

ADB	:	Asian Development Bank
BARC	:	Bangladesh Agricultural Research Council
BBS	:	Bangladesh Bureau of Statistics
BEMP	:	Bangladesh Environment Management Project
BL	:	Boro Local
BMD	:	Bangladesh Meteorological Department
BWE	:	Back Water Effect
CAP	:	Coastal Afforestation Project
CC	:	Climate Change
CCS1	:	Climate Change Scenario-1
CCS2	:	Climate Change Scenario-2
CEP	:	Coastal Embankment Project
CERP	:	Coastal Embankment Rehabilitation Project
CHT	:	Chittagong Hill Tracts
CO_2	:	Carbon-di Oxide
CPP-II	:	Cyclone Protection Project
DMB	:	Disaster Management Bureau
DMP	:	Disaster Management Policy
DoE	:	Department of Environment
DUV	:	Direct Use Value
ECA	:	Environment Conservation Act
ECR	:	Environment Conservation Rules
EIA	:	Environment Impact Assessment
FAO	:	Food and Agriculture Organization
FAP	:	Flood Action Plan
FCDI	:	Flood Control, Drainage and Irrigation
FD	:	Forestry Department
FFWC	:	Flood Forecasting Warning Center
GBM	:	Ganges, Brahmaputra and Meghna
GCM	:	General Circulation Models
GDP	:	Gross Domestic Product
GHG	:	Green House Gas
GoB	:	Government of Bangladesh
Ha	:	Hectare
HP	:	Horse Power
HYV	:	High Yielding Variety
Mha	:	Million Hectare
MoEF	:	Ministry of Environment and Forests
MP	:	Muriate of Potash

MSW	:	Municipal Solid Waste
MSWL	:	Mean Sea Water Level
MSY	:	Maximum Sustainable Yield
MT	:	Metric Ton
NA	:	Not Available
NGO	:	Non Government Organization
NUV	:	Non Use Value
NWMP	:	National Water Management Plan
NWP	:	National Water Policy
ppmv	:	Parts per million volume
RF	:	Reserve Forest
SBM	:	Sundarbans Bio-diversity Management
SBP	:	Sundarbans Bio-diversity Program
SEMP	:	Sustainable Environment Management Project
SL	:	Sea Level
SLR	:	Sea Level Rise
SMRC	:	SAARC Meteorological Research Center
SOI	:	Southern Oscillation Index
SPARRSO	:	Space Research and Remote Sensing Organization
SST	:	Sea Surface Temperature
SWMC	:	Surface Water Modeling Center
ToR	:	Terms of Reference
TSP	:	Triple Super Phosphate
TEV	:	Total Economic Value
UNDP	:	United Nations Development Project
UNEP	:	United Nations Environment Project
UNFCCC	:	United Nations Framework Convention on Climate Change
USCSP	:	United States Country Study Project
UV	:	Use Value
V&A	:	Vulnerability and Adaptation
WARPO	:	Water Resources Planning Organization
WB	:	World Bank
WBS	:	World Bank Study

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Executive Summary

Bangladesh is a broad deltaic plain country with most elevation less than 10 meters above the sea level. The main feature of the climatic condition and vulnerability of the country is severity of natural calamities and disasters because of reverine and coastal flood, tropical cyclone, storms surges, tornados, Sidr and droughts. Erratic precipitation coupled with climate change regime has adverse effects on the wetland resources, ecosystems, biodiversity and eventually the livelihood of the people. Salinity intrusion due to sea level rise has serious impact on the estuarine area and all forms of life of it. The empirical evidences indicated that this would continue to aggravate further following the upcoming more stress from the changed climate regime, unless it is addressed in time.

Agriculture, industry and services are the major economic sector of the economy. The contribution of GDP of agriculture sector was 22.0% in 2004-5, which was about 26.0% a decade ago. The revised estimate of GDP revealed that national GDP growth rate of the country increased over the years about 4-5%. About 70% of the export generated from agriculture. Various kinds of vegetables and spices are produced. About seventy percent employment is generated from the agriculture sector. Against this backdrop the study focuses on analyzing the implication of agriculture due to climate change.

The purpose of the study is to understand the extent of impact of climate change and it's implication for sustainable economic growth and development. The study found that effective disaster risk management is essential requirement for future economic development plan in order to overcome any threats and challenges of climate change. A long-term strategy and plan that effectively integrates structural, non-structural, human oriented innovations to reduce risk in connection with lesson learnt from the past. This will also help the nation for developing coping mechanism and enhancing the resilience of the people.

The study consists of ten sections; the first section of the study provides status physical environment of the country including the state of agriculture and other natural resources, which are basic means and subsistence of the people of the country. Here the findings of the earlier studies on climate change in Bangladesh are described briefly. The section two highlighted the integration of environmental impacts into policy analysis. This section also includes the rationale of undertaking the study of environmental cost for climate change and its implication for Bangladesh. The section three focused on purpose, objective and limitations of the study.

The section four and five explained the climate change scenario for Bangladesh in 2030 and 2050s. The section also focused on economic impact of climate change under different sea level rise scenario (SLR). This refers to costing of different events of climate change; this includes cost for floods 1998 in different sectors of the economy. The economic impact of climate change like flood 2004 in different sectors of the economy has also been discussed. The study analyzed the impact of flood and Sidr 2007, based on secondary sources of information of the study of Comprehensives Disaster Management Project (CDMP) and the information of study conducted by GOB-WB, 2008, especially the agriculture sector. This includes crop, livestock, fisheries, biodiversity loss etc.

The section six focused on climate change and agriculture, land degradation and production loss. This section also explains different types of land degradation and their extent including cost of land degradation in Bangladesh. Based on secondary sources information the study elaborated the distribution and extent of salinity in the coastal and offshore areas of Bangladesh.

The section seven is the crux of the study, where extensive review of literature has been made to develop framework for valuation of natural and environmental resources. In this regard a review on the concept of environmental valuation is made. For incorporating environmental impacts towards project analysis has a two-step process. First one is the understanding of what are the environmental impacts for undertaking a development project and future risk factor that economy might encounter due to climate change and natural disaster. This information is provided by a traditional economic analysis. Second one is estimating the value of environmental impacts (where feasible and appropriate) converting quality changes of resources and environmental degradation of services into money terms to determine their relative economic importance, and assess the benefits and costs of various alternatives. Total Economic Valuation presented a number of valuation techniques, which are potentially applicable to each category of value that have been described in the section.

It is known to all that environmental resources are different in nature and types, so no single theory and method is applicable for valuation of the environment. Because of data constraints and lack of appropriate modeling tools and techniques as well as technical expertise in the developing countries, it is very difficult to make the environmental valuation perfectly. But experience and real life scenario show that it is worth learning to begin with something, instead of doing nothing. In this section types of environmental valuation and types of environmental services have been discussed. This section described total economic valuation of environmental resources, this includes, direct, indirect, option values, bequest and existence valuation approaches.

The section nine focused on the findings for economic loss under several climate change scenario. The findings of the study demonstrated that impact of climate change on agriculture would seriously affect the total agriculture production in general, and the crop agriculture in particular. The study found that the vast coastal croplands suffer from salinity related problems in the winter. This is particularly common in nearly 1.0 Million ha salt affected soil in the coast. Because of cyclone and storm surges, high spring tide inundation and capillary actions salt accumulate at the surface and root zones. On the other hand due upstream intervention fresh water salinity intrusion is adequately neutralized. As a result, a large area in the coastal districts is virtually unsuitable for existing practice of crops. About 0.13 Million ton food grain is lost annually due to adverse impact of soil salinity. Thus, due to extension of saline area and salt affect, crop loss will be higher in the future. This needs urgent attention for policy makers to address the issue without further delay.

In the final section, the study highlighted the importance of determining the economic costs of the impacts of climate change for the country and region, which is affected due to climate change. This needs economic modeling and comparisons of current level social costs with future trajectories. The study also emphasized that economic impact of climate change event is very essential for future economic planning and design, promoting technologies, propagating biotechnologies and future investment planning of the country as a whole. The review of climate change issues provides for the country prepare a road map along the findings to apply and create some leverage and argument in the climate change negotiation to demand and seek necessary and adequate investment funding to ensure climate resilient development for the future.

1.0 Introduction

Bangladesh is a broad deltaic plain country with most elevation less than 10 meters above the sea level. The main feature of the climatic condition and vulnerability of the country is severity of natural calamities and disasters because of riverine and coastal flood, tropical cyclone, storms, surges, tornados, Sidr, and droughts. The rainfall is mostly confined during the monsoon ranging from 1524 mm to 5000 mm on average annually (BBS), which is a critical risk factor for agricultural production. There are three main period of rain fall: (i) the western depression winter (ii) the early thunder storms known as Nor'westers (North Westerlies) and (iii) the summer rains from the south west trades known as the monsoon.

The country located on the Bengal delta, which is situated at the confluence of three mighty and big rivers namely the Ganges, the Brahamaputra and the Meghna. The plain land is intersected by numerous rivers, *khals* (small channels) and backwaters. The total length of the drainage channel was estimated more than 20,000 km. The alluvial soil is continuously being enriched with heavy silts deposited by rivers. About 2 billion tons of sediments is eroded from the Himalayas by ice, snow and rainwater and is transported to Bangladesh coast by rivers annually (Viles and Spence, 1995). Most portion of the land used for agriculture, forest and habitation. Less than one per cent of the area is used for industry and other miscellaneous social needs.

Physiography: In the context of physiography, Bangladesh can be divided into three divisions as follow:

a) Vast alluvial flood plains are almost continuous and flat, which is hardly 9 meter above the mean sea level. This occupies almost 80% of the total land area. This plain land is covered by a large number of rivers.

b) Uplifted land blocks are the remnant of an old phase of deposition that occupies about 8% of total land area of the country. It comprises two major tracts namely Barind tracts and the Madhupur tract and minor tract called Lalmai hills. The heights of the tract in most cases are 1-5 M and in some places they are up to 25 meters above adjoining flood plain (Huq et.al.., 1999).

c) The Marginal Hills of the East and the South East are situated along the northern and eastern borders of Bangladesh, which covers the area of 12% of the country. The Hills are normally 10-100 meters above mean sea level.

Bangladesh is endowed with humid tropical climate. Rains start in March –April and end during mid October with an average 1500 mm year^{-1} in the dryer region to 5000 mm year^{-1} in the wetter regions. Winter in Bangladesh covers the period from November to February. During this period the average maximum and minimum daily temperature are about 9.7 ^{0} C and 26.6 ^{0}C respectively. Summer is the hottest period of the year with temperature over around 32.2 ^{0}C but rarely exceeding 40 ^{0}C.

Population: Population of the country according to the last census conducted in 2001 was 129.1 million with annual growth rate (1991–2001) of 1.47%. Population density of the country was 834 per km^2 in that period; by 2006, it rose to more than 900 per km^2. Over 65% of the country's population is rural living on agriculture. In search of employment opportunities the rural to urban migration is accelerating at an alarming rate. According to

1995-96 Labor Force Survey, the total civilian labor force of the country was estimated at 56.0 million, of which 34.7 million are male and 21.3 million are female.

Agriculture based economic activities: Agriculture, industry and services are the major economic sector of the economy. The contribution of GDP of agriculture sector was 22.0% in 2004-5, which was about 26.0% a decade ago. The revised estimate of GDP revealed that national GDP growth rate of the country increased over the years about 4-5%. The annual average growth rate of agriculture was estimated at 1.6% against 6.9% in the industrial sector and 5.1% in the service sector at current prices during 1991-95. The agricultural growth rate is estimated at 5.04% for 2001 (BBS 2001). About 70% of the export generated from agriculture while sustaining about 74% of male labor force and 48% of female labor force. Rice, wheat, jute, sugarcane, tobacco, oilseeds, pulses and potatoes are the principal crops of the country. Various kinds of vegetables and spices are produced. The country produces about 51 million kg of tea and 1057 thousand MT of superior quality jute per year. About 16% of the export earning comes from raw jute and jute goods. Among the fruits; bananas, mangoes, pineapples, papayas, jackfruits and coconuts are important.

Agriculture, which includes land based and biomass producing activities will likely to be the most affected sector due to climate change. The impact of climate change in agriculture implies the potential changes in crop yields, fish, livestock and forestry changes in the productivity and net production that poses a threat to national and regional food security causing a profound effect in the poor of country. The principal export items of Bangladesh include ready-made garments, raw jute, jute products, tea, fish, hides and skins and newsprints.

Fish and Aquatic Resources: Bangladesh is rich in fishery resource. In the numerous rivers, flood plains, haors, beels, paddy fields and other low lying areas (covering about 5 million ha), tropical fishes of hundreds of varieties are abound. Culture fisheries are widely practiced in the country and this sector is enlarging day-by-day. Hilsa, lobsters and shrimps are one of the main sources of export earning of Bangladesh. With the Bay of Bengal in the south the country enjoys geographical advantage for marine fishing.

Fisheries industry represent only 8% of agricultural GDP, but it fully employs 1.5 million rural people and provides partial employment to another 11 million. Fisheries contributed 10% of the total export earnings in 1994-95 periods (WB, 1997). Rivers, lakes, haors, baors, beels and household ponds produce about 600,000 metric tons of fish annually that make up nearly 80% of the total animal protein consumed in the country. In the wet season, inundated flood plains serve as breeding ground and nursery for fish.

Forestry and Wildlife: The total forest area covers about 17% of the land area of the country. Bangladesh produces timber, bamboo and cane. Plantation of rubber in the hilly regions has been undertaken. The coastal region of Bangladesh houses several mangrove ecosystems, including the Sundarbans. It is known as the single largest stretch of productive mangrove forest in the world and is inhabited by one of the most elegant creature of the nature, the Royal Bengal Tiger. Sundry (Heretiera fomes), gewa (Excoccaria agellocha) and goran (Ceriops decandra) are the most abundant species found in the forests. Many other flora species exist in these areas. Varieties of wild animals are found in the forest areas of the country. Among them elephants, bears, deers, monkeys, boars, leopards, crocodiles etc. are worth mentioning. A few hundred species and sub-species of birds are found in the country. Some of them are of seasonal and migratory types.

Coastal Ecosystem: The Ganga-Jamuna deltaic plain encompasses an area of 2.5 million hectares of coastal tidal land. The length of the coastline is approximately 700 km. Much of this area is ideal for brackish aquaculture and tropical shrimp culture (Rahman, 1994). As a result, a large shrimp culture industry has developed in the coastal area. Traditional open sea fishing and drying on land is also a common practice along the coastline.

Navigation and Transportation: Bangladesh has an intricate network of khal, beel, hoar, baor and river, which is used as navigational channels year round. In the monsoon, water level in many parts of the country rises 6m or more and waterways become very wide spread. According to Inland Water Transport Authority (IWTA, 1999), the total length of waterways in rainy season may exceed 8000 km. At the end of dry season, this length may shrink to about 4800 km. But for country boats the total length in the rainy season may extend to 24,000 km.

Due to siltration of many rivers and improved road network, transport via waterways is decreasing all over the country. The major inland ports that carry substantial amount of freight and passengers are Dhaka, Narayanganj, Chandpur, Barisal, Khulna, Potuakhali, Narsingdi, Bhairab Bazaar and Azmiriganj. Some of the ports – Dhaka, Narayanganj, Chandpur, Baghabari and Azmiriganj may be developed as container ports in future. Bangladesh has two seaports: Chittagong and Mongla. Chittagong has been used as an international port for more than a thousand years. Mongla port, which is located 48 km south of Khulna on Passur River, was established in December 1950 and since then, it has grown rapidly. All these infrastructure and facilities under threat due to sea level rise because of climate change.

Disaster and Natural Calamities: The climate of Bangladesh is mainly dominated by the tropical monsoon from May to September. Annual average rainfall ranges from 119 cm to 235 cm (BBS, 1998) most of which occur during the monsoon and mean daily temperature ranges from $18^{o}C$ (December-February) to $30^{o}C$ (April-May).

Several recent published studies on Bangladesh found that:

a) In the next 50 years, Bangladesh may experience upto one-third of a meter rise in sea level, a few degrees celsius increase in temperature, and upto a 30% change in precipitation. Cyclone intensity may also increase. Although these average changes in climate may appear small, addition of these changes to observe extreme events make a repeat of those events, even more destructive to Bangladesh.

b) Sea level rise could inundate a significant portion of low-lying coastal areas of Bangladesh. More intense storm surges, particularly on top of sea level rise, could result in more death and elimination or loss in low-lying coastal areas of Bangladesh.

c) Increased precipitation, particularly in the monsoon period, could increase flood depth and extent. There is a potential for drier conditions during the dry season (winter), which could make droughts worse.

d) Bangladesh is already vulnerable to many infectious diseases, warmer and wetter conditions could make the potential for spread of diseases greater.

e) Climate change poses a threat to ecosystems in Bangladesh. At particular risk is the Sundarbans, which could be largely inundated by sea level rise.

f) Increase in the frequency and intensity of extreme events, include possible disruption of the El Nino cycle, increases in cyclones and storm surges. The coastal zone is particularly vulnerable covering about 30% of the country.

g) The unplanned and indiscriminate development efforts of the country without taking into consideration of the cost of climate change, there is direct impact on threatening the livelihood security, worsening health hazard, reducing food production, causing land degradation, depleting natural resource base, degrading potential ecosystem services and over all environment of the country.

The country enjoys a sub-tropical monsoon climate. The country has six seasons but four major prominent seasons in a year are important for discussion. These are winter (December-February), pre-monsoon (March-May), monsoon (June-September) and post-monsoon (October-November). Average annual temperature varies from 19^0C to 29^0C. The average annual rainfall ranges from 1429 to 4338 mm, which also not balanced over the year. About 80% of the total rainfall of the country occurs during monsoon (July-September). The maximum rainfall is recorded in the northeastern part (Sylhet), while the minimum is observed in the western and northern parts of the country. Both are either extreme with flash flood or drought.

2.0 Integration of Environmental Impacts Into Policy Analysis

In conventional cost benefit analysis, environmental effects have not been considered adequately. In such cases, the Cost Benefit Analysis (CBA) outcome (IRR, NPV) then fails to provide a comprehensive picture of project's efficiency. The current practice of environmental protection provides a strong stimulus to economists to devote more attention to valuation of environmental effects. In contrast to many man-made products, environmental goods and services are not often traded in markets. Environmental amenities such as clean air, natural beauty, cultural heritage, ozone depletion can not be traded, because of lack of ownership and its transferability, such amenities lack market price. Environmental effects are typically external, where it is very difficult to put market price for those resources.

Therefore there is no direct price indicator for the value to society of changes in the air quality, siltation (side effect of irrigation project) sedimentation (side effect of dam project). For natural resources traded (fish, land) the market price usually is a poor guide to the value to society. There are various ways for valuation of environmental costs and benefits. For example, the value of the ecological effects (increased erosion) might be estimated by investigating the loss of agricultural production it causes, similarly, the ecological benefits of an erosion control project (reduced erosion) may be valued in terms of resulting increase in agricultural output. Therefore, values of ecological costs are the benefits foregone in agriculture; a proxy for the value of ecological benefits is the avoided costs in agriculture, which is called opportunity costs approach.

Prior to undertaking a project, the first task would be identifying and measuring the environmental impacts that are often dislocated in times and space making cause and effects. It is very difficult to identify the impact and measure them properly over time and space. Besides, many environmental goods and services do not have market price doing so only imperfectly. More over non-availability of data (and /or poor quality of information) in the developing countries like Bangladesh are not reflecting the real picture of the environmental effect. In undertaking an economic analysis the important things to be taken care of include (i) the economic analysis that normally consist of estimating monetary costs and benefits (valuation) of the various environmental impacts identified in the EIA, using a range of *valuation* techniques: (ii) the analysis may extend to consider the costs and benefits of preventive and mitigation measures for comparison with the original project impacts; (iii) the monetary values for the selected alternative towards integrating into the overall economic *evaluation* of the project to be undertaken.

2.1 Rationale of the Study of Environmental Cost for Climate Change

The global climate change and frequent change in the variability of the climatic condition of the country shall have direct impacts on the environment in various ways. Erratic precipitation coupled with climate change regime shall have adverse effects on the wetland health, ecosystems, biodiversity etc. The similar implication it has on the vegetation coverage of the country as regard ecosystem services. Salinity intrusion due to sea level rise has serious impact on the estuarine area and all forms of life of it. The empirical evidences revealed that this should continue to aggravate further following the upcoming more stress from the changed climate regime.

2.2 Economics of Climate Change: Implications for Bangladesh

In order to analyze the economic implications of climate change regime a stern review was made public on 30 October 2006 on impact of it. Since then, it has been a subject of much discussion and debate everywhere. This independent review was commissioned by the Chancellor of the Exchequer for reporting to both the Chancellor and to the Prime Minister, United Kingdom, as a contribution to assessing the evidence and building understanding of the economics of climate change. The evidence gathered by the Review leads to a simple conclusion: the benefits of strong early action considerably outweigh the costs.

Modeling work undertaken by the review suggesting that the risks and costs of climate change over the next two centuries could be equivalent to an average reduction in global per capita consumption of at least 5%, now and forever. The estimated damages would be much higher if non-market impacts, the possibility of greater climate sensitivity, and distributional issues were taken into account. This it needs a contingent investment for emergency response, immediate rehabilitation and restoration of the economy.

"All countries around the world will be affected due to climate change. The most vulnerable – the poorest countries and populations- will suffer earliest and most, even though they have contributed least to the causes of climate change. The costs of extreme weather, including floods, droughts, storms and cyclone like Tsunami and Sidr, are already rising, including the rich countries. Adaptation to climate change – that is, taking steps to build resilience and minimize costs – is essential. It is no longer possible to prevent the climate change that will take place over the next two to three decades, but it is still possible to protect our societies and economics from its impacts to some extent – for example, by providing better information, improving planning and more climate – resilient crops and infrastructure. Adaptation will cost tens of billions of dollars a year in developing countries alone, and will put still further pressure on already scarce resources. Adaptation efforts, particularly in developing countries, should be accelerated."

The review made recommendations, considering Adaptation as one of the three elements for future international frameworks: The poorest countries are most vulnerable to climate change. It is essential that climate change be fully integrated into development policy framework, and project design. The rich countries honor their pledges to increase support through overseas development assistance. International funding should also support improved regional information on climate change impacts, and research into new crop varieties that will be more resilient to natural disaster and calamities.

Against this backdrop, efforts need to be made to determine the economic costs of the impacts of climate change for Bangladesh. This needs to address the physical impacts of climate change on the economy, on human life and on the over all environmental impacts of the country. This requires economic modeling and comparisons of current level social costs of carbon with future trajectories. This is also important for future economic planning and design, promoting technologies, propagating biotechnologies and future investment planning as well.

The review provides substantive directions for Bangladesh. First, Bangladesh can review the existing framework and develop its own framework for modeling climate change and its economic implications. Further, Bangladesh can prepare a road map along the findings to apply and create some leverage and argument in the climate change negotiation to demand and seek necessary and adequate investment funding to ensure climate resilient development.

To do so, it will be necessary to contextualize the arguments, principles, methods and analyses contained in the review to define and describe our “economic vulnerability” and ascertain the magnitude of investment to facilitate the overall economic growth and performance of the economy.

The economic analysis and modeling for Bangladesh’s vulnerability and susceptibility to climate change, disaggregated across sectors, could indicate investment requirements to assure climate resilient development. The adaptation deficit for Bangladesh can be determined to a large extent from such analysis. This could contribute greatly to rationalize and secure funds from development partners.

The Working Paper recently published from the Climate Change Cell 2007 titled "Climate Resilient Development Country Framework to Mainstream Climate Risk Management and Adaptation" offers a generic tool/process that can be adapted and contextualized for a country to operationally mainstreaming at all levels, across all sectors.

The Country Framework to implement mainstreaming climate risk management and adaptation serves a wide range of needs. It provides a way for every country to integrate climate risk and adaptation practically. It enables each country to assess and determine the scope and level of adaptation and risk management across different sectors on a continued basis, and over time, at each level of operation.

This calls for development efforts to integrate climate risk management such that development becomes resilient to climate changes. Thus mainstreaming climate risk management and adaptation into development planning and processes is the first foundation that each country must establish which is critical and paramount. The problem and concern is too complex and overwhelming to consider anything less in order. This provides the basis to ensure systematic assessment of risks, exploring options for management, and calculating the investment needs for climate resilient development and the value of the damage avoided.

Further, sharing of our mutual concerns and options can play a vital role toward consensus building, leading to common positions in key areas, for collective bargaining in international processes and institutions such as the UN Commission for Sustainable Development (UNCSD), United Nations Framework Convention on Climate Change (UNFCCC), International Financial Institutions.

3.0 Purpose of the Study

The purpose of the study is to explore the extent of impact of climate change and its implication for sustainable economic growth and development. This refers to effective disaster risk management which is essential requirement for future economic development plan in order to overcome any threats and challenges of climate change. A long term strategy and plan that effectively integrates structural, non-structural, human oriented innovations to reduce risk in connection with lesson learnt from the past. This will also help the nation for developing coping mechanism and enhancing the resilience of the people. Thus it clearly emphasizes the rationale of conducting the study.

3.1 Objectives

In order to address the climate change risk factors in the development process the objective of the study is to design and develop a framework for assessing and estimating environmental cost (value) of the climate change scenario. This includes to review existing literature, identify resources stock, their characteristics and their changes over time. Analyze the implications and evaluate the importance and value of ecosystems and the over all environment, threats of resources depletion and the over environmental degradation especially due to climate change. Considering the diversity and complexity of the stock of resources and their services attempt has been made for developing a framework for estimation of environmental cost, particularly for climate change risk and vulnerability.

With the given timeframe and budgetary constraint for the study, the attempt is made to review the literature on the subject in order to develop a framework for total economic valuation. Some estimation efforts have been made on agriculture sector only for tangible resources. In order to capture the benefits of intangible resources, it needs quite a great deal of time to work on modeling. The information requires yet to be made available in this context. Developing a theoretical framework will be no doubt a good beginning.

3.2 Limitation of the study

The study conducted is based on the secondary sources of information, published and unpublished reports. Interpretation and analysis have been made to the context of current and future climate change threats and challenges. In certain cases where information and references are not available author's own judgment and understanding have been applied. Other experts of course can disagree and debate with some observations for variety of reasons, based on socio-economic dimension, cultural settings, physical environment and ecological conditions. Analyses carried out and policy directions indicated in the report however, expected to be useful for future economic plan towards sustainable development.

4.0 Climate Change Scenario in Bangladesh

Climate change is a long-term phenomenon and the scenario for Bangladesh developed under United States Country Study Program and World Bank Study. Potential effects of climate change are considered for the period from the present to 2050. A climate change scenario for Bangladesh in 2030 and 2050 is presented in the Table-1.

Table 1: Climate change scenarios for Bangladesh in 2030 and 2050

Year	SLR (cm)	Temperature increase (^oC)	Precipitation fluctuation compared to 1990 (%)	Changes in evaporation
2030	30	+0.7 in monsoon +1.3 in winter	-3 in winter +11 in monsoon	+0.9 in winter +15.8 in monsoon
2050	50	+1.1 in monsoon +1.8 in winter	-37 in winter +28 in monsoon	0 in winter 16.7 in monsoon

Source: Initial National Communication of Bangladesh for UNFCCC, 2002

Looking into the **sea level rise**, IPCC projected that by 2100 the sea level will rise in the range of 15 cm - 95 cm by 2100. In Table-1 it is projected that by 2030 SLR would be about 30 cm and by 2050 it would be about 50 cm. Even a very cautious projection of 10 cm sea level rise, which would most likely happen within 2020, would inundate about 2500 km^2 (about 2% of the total area of Bangladesh) in Khulna, Patuakhali and Barisal regions.

In terms of **temperature,** climate change projections for further increase of average surface temperature close to 1-5^{0}C by 2100 as compared to the last decade of the last century.

Considering the **precipitation** factors most models show that there would be increasing precipitation in Bangladesh. Some models also showed the possibility of increasing monsoon precipitation (May to September) and decreasing dry season precipitation (December to February).

For Bangladesh the projection of this study are: a 0.7^{0}C temperature rise in monsoon and 1.3^{0}C temperature rise in winter by the year 2030. It will induce higher **evapo-transpiration**. As such, more water will be needed for the plants and on the other hand, there will be scarcity of surface and ground water.

Some studies reported that the **El Nino Southern Oscillation (ENSO)** events influenced the record-breaking floods of 1987, 1988 and 1998 in Bangladesh (Choudhury, 1998). The rapid transformation of La Nina from El Nino phase in early monsoon in 1998 is said to have influenced high rates of precipitation over the entire GBM catchments basin. As a result, after a prolonged dry season, the wettest monsoon came along with extremely high levels of precipitation that would result in the deluge of the century. Such global events could therefore intensify some of the extreme climate change related weather events further.

Storm surges, seasonal flooding, widespread poverty, large population base, etc. have made Bangladesh vulnerable to climate change. Climate change induced vulnerability is related mainly to biophysical, climatic and socio-economic situation of the population. Floods and droughts are frequent and damaging the agriculture of the country (Karim, 1995 and Huq *et al*. 1996). The most affected crop due to flood and drought is the rice of different type. Rice alone contributes 93% of the total cereal production followed by wheat 5.81% and the rest

0.23% by other crops. Average productions per acres for the year 1999-2000 and 2005-06 have been given in the Table-2. Table 2 indicated that area of HYV Aus production increased from 2000-01 to 2005-06, but yield decreased slightly. Area of HYV Aman production decreased but yield of it increased over the same period. The area of HYV Boro production increased from 8,533 to 9,321 thousands acres but yield declined from 1.565 to 1.515 Ton/acre. Here important aspect to note that both area of production of other rice and their yield increased significantly over the same period. The area of wheat production and its yield have decreased. This signifies that cropping pattern is getting changes over time in order to adapt climate from own initiative of the farmers. This needs urgent attention for adopting appropriate policy measures.

Table-2: Crop statistics of major cereals for the fiscal year 1999-2000 and 2005-06

	2000-01			2005-06		
Rice	**Area '000' (Acres)**	**Production Ton**	**Ton/acre**	**Area '000' (Acres)**	**Production Ton**	**Ton/acre**
HYV Aus	1,094	998,585	0.913	1,167	1,056,065	0.905
HYV Aman	6,886	4,061,912	0.590	6,615	4,295,724	0.649
HYV Boro	8,533	13,353,255	1.565	9,321	14,121,895	1.515
Other Rice	10,167	6,672,248	0.656	8,915	7,056,316	0.792
Total Rice	**26,681**	**25,086,000**	**0.94**	**26,018**	**26,530,000**	**1.020**
Wheat	1,909	1,673,000	0.876	1,184	735,000	0.62

Source: BBS, 2001 and Year Book of Agriculture Statistics of Bangladesh, 2007 and Monthly statistical Bulletin, January, 2008

4.1 Economic Impact of Climate Change

Sea level rise: One of the direct and major consequences of climate change is the sea level rise. There are two mechanisms to take it place: thermal expansion of near surface ocean water and melting of snow fields, ice sheet and glaciers. The most important impacts of sea level rise are the loss of land use due to inundation. All the impacts have the negative consequences on agriculture and economy of the country. Most of the grazing lands in the coastal belt will be lost and for this reason loss of production in crop, fishery and livestock in the coastal zone will create pressure for more intensive cultivation and will be an adverse effect on the soil fertility and agricultural land productivity of the country. There will be displacement of huge population, loss of land, forest and fisheries and other resources. The average sea level rise for Indian coast has been reported as 2.5 mm/year since the 1950s (Climate Change in India 2001). A recent study by Singh et al., (2000) found that tidal level at Hiron Point (21^o 48' N, 89^o 28' E), Char Changa (22^o 08' N, 91^o 06' E), and Cox Bazar (22^o 26' N, 91^o 59' E), indicating an increase of 4.0 mm/ year, 6.0 mm/ year and 7.8 mm/ year respectively, which is higher than the global rate. This higher tidal rate attributed to subsidence. In the estimate 22 years tidal data have been used (Anwar Ali 2000). No doubt other specific data will provide different results.

Various predicted scenario have been shown in Table 3 due to sea level rise. It is predicted that about 2%, 5%, 10% and 15% land will be lost due to sea level rise 10 cm, 30 cm, 1 m and 1.5 m respectively. The major factors considered responsible for sea level rise are non-uniform rise in temperature, accelerated rise in the temperature, geological subsidence and increase of sedimentation.

Table 3: Estimated inundation and loss of land under different SLR scenario

Seal Level Rise (m)	Inundation (km^2)	% of total Country inundation	Loss of land due to erosion by SLR (ha)
0.10	2,500	1.7	7
0.30	8,000	5.4	21
1.0	14,000	9.5	71
1.50	22,320	15.2	107

Source: Anwar Ali, 2000

SLR would increase the present rates of erosion, thereby resulting in the loss of land and increasing the vulnerability of coastal communities. Any acceleration of erosion due to sea level rise will contribute to an increased loss of land and thereby affecting communities and economic activities. The distribution of Aus (Fig 1), Aman (Fig 2), Boro (Fig 3), and wheat (Fig 4) production in the country are presented below.

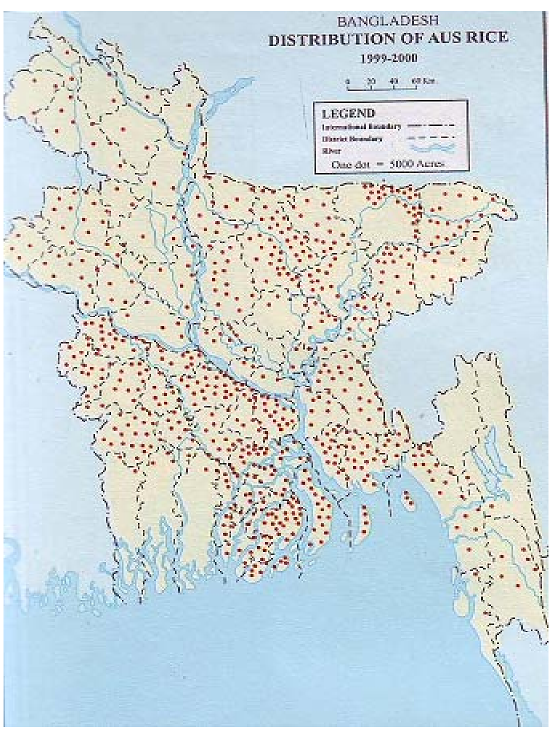


Fig 1: Area of Aus Production

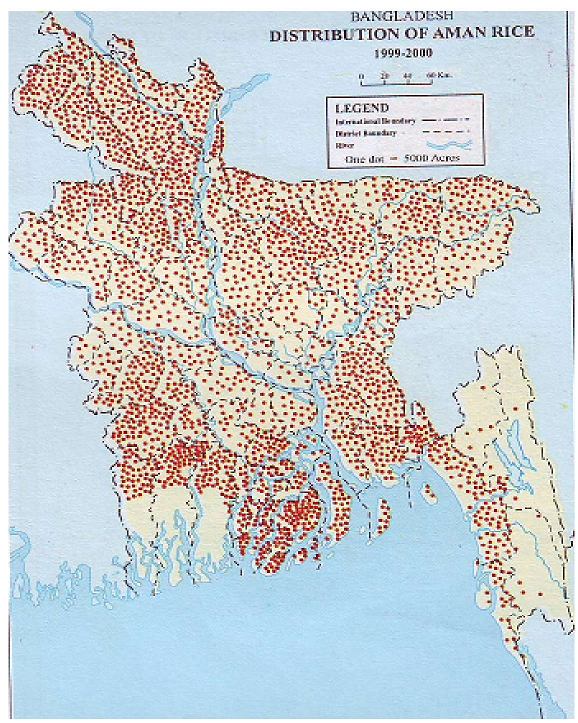


Fig 2: Area of Aman Production

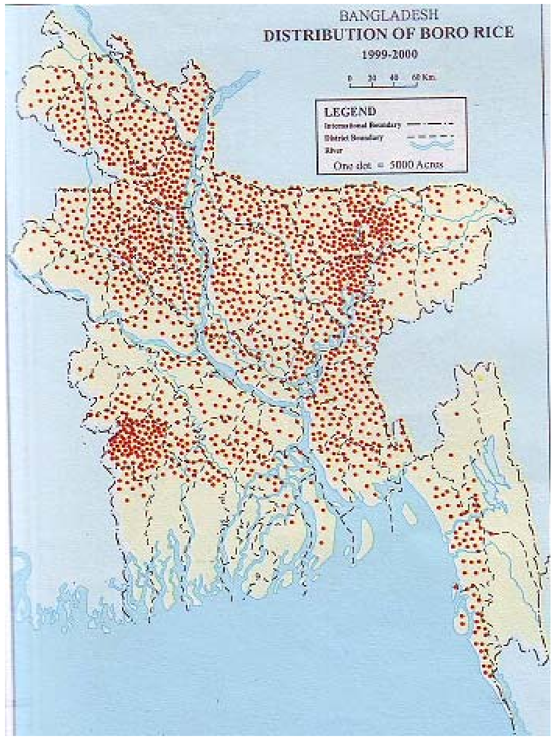


Fig 3: Area of Boro Production

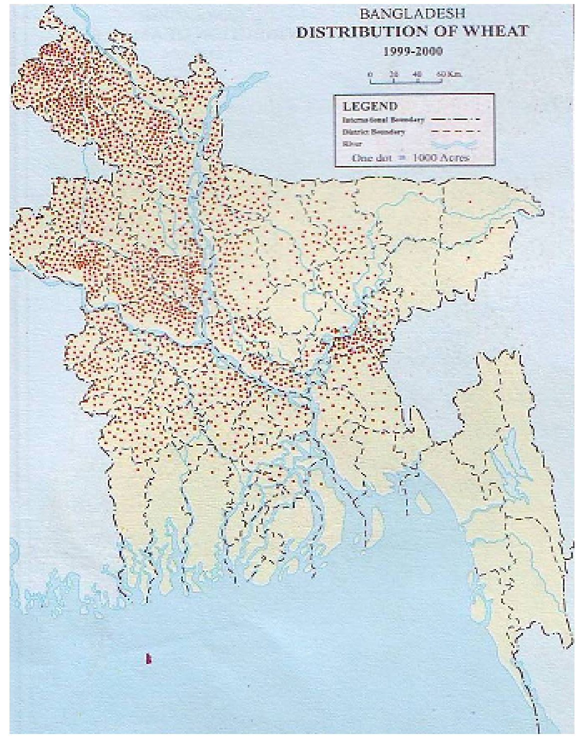


Fig 4: Area of Wheat Production

Higher water levels would provide storm surges with a higher base to build upon and higher water levels would decrease natural and artificial drainage; this could also lead to pollution of water bodies. It is also recognized that change in climate due to global warming could contribute to the reduction of the return periods of storms and floods, thus increasing the frequency of extreme events. This will cause disasters in which there will be large losses of lives, property and infrastructure.

Climate change is likely to change the water flow and hydrological cycle of the country. It is clearly evident that Bangladesh has the main two sources of water flow; one from upstream Himalayan and the other is the round the year precipitation in the country.

Change in the climate will cause the melting of ice resulting an increase of intensity and severity of monsoon in the south –west of the country. This will bring about catastrophe ravages like erosion of topsoil and siltration of rivers and landslides in hill areas caused flash flood and overflowing of the agricultural land. The growth of the plant is hindered by the flood due to excessive moisture at the root zones, resulting in an overall decline in production of the crop. Transplanted Aman paddy does not grow well under submerged conditions of over 90 cm water depth. Such a relationship with water depth (or moisture availability), however, is variety specific. About 1.0 Mha of cropland is highly and nearly 5.0 Mha is moderately flood prone area. Usually, the flooding depth varies from 30 to 250 cm. The extent of the unprecedented flood of 1998 inundated two-thirds (8.4 Mha) of the country. The estimated loss of food grain well exceeded 3.5 Mt. The flash floods often damage boro rice. The increase of rainfall with the change in climate in future would produce even more severe floods of different nature causing severe damage to rice crop and others.

5.0 Costs for Flood 1998

Flooding is a normal part of ecology of Bangladesh. Due to climate change abnormal flooding become a standing feature of the country. The 1998 flood was an extreme event, when around a quarter of the country experiences inundation. At its peak, the flood covered three thirds of the country. More than 1000 people died and more than 30 million people were made homeless. About 10% rice crop of the country was partially or fully damaged. During rehabilitation and replanting, millions of households faced food security crisis. Large scale food imports and government food aid was transferred and utilized for humanitarian catastrophe. The big portions of children were suffering from malnutrition after flood, which was almost double of the normal period. Households adjusted to the flood in several ways. Reduced spending, asset sales, and increased borrowing all featured.

The economic loss due to damage incurred during flood 1987 estimated at US$ 1,000 million and for that 1988 it stood at US$ 1,200 million. The 1988 flood caused over 1517 deaths. The death toll in 1998 was less than 1000 and considerable reduction in livestock deaths from 35,000 in 1988 to 26,564 in 1998. This was possible due to improvement of flood preparedness and management. The 1998 flood however forced over a million of people out of their homes, damaged 16,000 km roads and 4500 km of embankment and destroyed crops on more than 500, 000 ha of land (WARPO, 2001).

Economic Impact of Flood on Water Supply: The water supply system of DWASA in 150 km^2 out of 250 km^2 service area was inundated by flood. These include production wells, distribution network, street side taps, ground level water reservoirs located in the inundated and submerged areas. An estimate of cost for repairing and rehabilitation of DWASA 1998 stood at Tk 620 million. Similar estimation of economic loss because of recent two consecutive floods 2007 and immense economic loss incurred due to Sidr of December 2007 in the coastal area of the country may provide the cost for climate change.

Cost for Housing Damage: A study conducted in 1998 for estimating the damage cost of housing identified five types of housing which include *pucca*, semi *pucca*, *katcha*-1, *katcha*-2 (*Jhupri)* and temporary housing. The total cost of damage for housing was estimated at Tk 2,311 million due to the flood.

Economic Impact of Transport Sector: During the flood, officials of Dhaka City Corporation (DCC) estimated that per kilometer (km) damage to highways would stand around Tk 84,800. For a paurashava the cost was estimated at Tk 42,000. Dhaka City Corporation requested a fund from the government for repairing more than one fourth of the road network in Dhaka; more than 600 km out of 2300 km roads were damaged. The time cost and work loss due to disruption of the network is yet to be estimated that will eventually affect the national economy substantially. Thus the total damage incurred in the road sector for Dhaka city estimated at (Tk 84,800 x 600 = 508,80,000) Tk 51.0 million. The economic impact for damage in the railway, waterways and airways sectors yet to be estimated which seem to be not less the said amount.

5.1 Loss of Utilities Service

Economic Impact to the water infrastructure: The study also found that about 60% of water supply system of Dhaka WASA was affected by the flood in Dhaka city (Ahmed, 1998). Dhaka WASA reported that about Tk 81.0 crore would require for repairing / rehabilitation of damaged infrastructure, of which Tk 62.0 crore would require for sewerage system, Tk 11.0 crore for water supply system and Tk 8.0 crore for storm water drainage system.

Damage to Electricity Infrastructure: In estimating economic impact of 1998 flood DESA reported that electricity infrastructure of DESA that have been damaged include: (i) 33 kV lines (ii) 11 kV lines, (iii) Low Tension line (LT), (iv) High Tension Line (HT) (v) Low Tension (LT) cables (vi) Transformers (vii) Circuit Breakers (CB) and RMU. Besides, some vehicles and buildings of the department were also damaged by flood water. The cost of damage was estimated at Tk 35 crore (DESA Report 1998) .

Damage to Telephone Service Infrastructure: The study reported that the damaged infrastructure of T& T was also quite extensive; this includes, primary cable, secondary cable, cabinet (its CT boxes and joints), distribution point and dropper. According to T&T information due to flood a total of 1,817 telephone connections were disrupted under the four telephone exchanges of DTR (North). The total damage estimate for DTR (South) stood at about Tk 6.6 crore and that for DTR (North) at Tk 6.31 crore (Nishat et al, 2000; p124).

Economic Loss in Education Sector: In order to estimate the economic loss of the damages for the city educational institutions, the implication of economic loss was quite diverse to quantify like physical damages of institutions, loss of sessions of classes and consequential shortening of the academic year, damage of the teacher and students' housing and amenities, student loss due to damages of their education materials and equipments. (v) A partial estimation showed that only for the rehabilitation of affected institutions in Dhaka city and Kamragirchar would cost at Tk. 44.0 million and Tk 1.77 million respectively (Nishat et al, 2000: p 139).

Economic Impact on Biodiversity and Ecosystem: The vegetation in Dhaka city is very limited. The total economic loss for the livestock was estimated at Tk 17.3 million, fisheries at Tk 1.39 million poultry at Tk 2.0 million and nurseries at Tk 0.5 million. Many unrecorded resources are still left to be captured for economic valuation. This is very difficult part of estimating economic and environment loss due to water and air pollution that can be made using indirect method like health cost and productivity loss.

Economic Impact on Trade: A rapid assessment of the 1998 flood shows that the flood caused huge amount of property losses, four major sectors are manufacturing, trade, office & public buildings and crops. The study estimated that the selected large industries incurred damage of Tk. 210 crore while loss of small and medium industries estimated at Tk. 254 crore. The loss to trade sector estimated at Tk 90.4 crore and loss to office building and public buildings estimated at Tk 5.0 crore. Total estimated loss to crop sector stood at Tk

2.52 crore. Thus total loss caused to properties in the selected sectors mentioned in the city estimated at Tk 578 crore (Nishat et al 2000; P 180).

5.2 Economic Impacts of flood 2004

The flood of 2004 has damaged of about 2500 km embankment, 120 km protective works, and 545 hydraulic structures, affecting about 30 million people with more than 500 people dead. The economic loss has primarily been estimated at US$ 600 million, which is subject to vary.

Impact of Flood in the Railway Sector: During the devastating flood of 2004 most of the areas of Bangladesh were under water. The railway department estimated the rehabilitation cost at Tk1270.0 million, which was at Tk1020.0 million for 1998 flood. The preliminary estimate of damages on RHD road infrastructure due to flood 2004 stands at Tk 946.80 crore. In case of rural infrastructure it was estimated at Tk 9,296 million. In case of Dhaka City an estimate of Dhaka Urban Transport Project (DUTP) revealed that it will require about Tk 257.0 million for the maintenance of damage roads. In case of Non-DUTP flood damage roads estimated at Tk 10.25 million.

The economic loss and impact for the livestock for 2004 flood has been estimated at Tk 204.11 million. Regarding the impact on garment industry, the Export Promotion Bureau estimated loss at Tk 3,258 million which also includes delayed shipment. The loss for the forestry sector was estimated at Tk 783 million. The estimated damage cost in the power sector stands at Tk 1,017 million as a whole. The unserved loss for energy sector was estimated at Tk 5.12 million. The loss for the telecommunication sector has been estimated at Tk 186.2 million. For repairing the damage of 108 km fiber Optic link between Dhaka-Chittagong, the cost was estimated at Tk 25.1 million.

Salinity: A sea level rise causes salt water intrusion into rivers and estuaries resulting infiltration of salt water into coastal aquifers. In Bangladesh under ground water is used for domestic use and irrigation purposes. Sea level rise also causes to increase in salinity in underground water that has resultant impact on human health and agricultural productivity. The southwestern part of the country already has a suffering of salinazation due to reduction of the flow of Ganges. Pressure of seawater towards inland will induce greater and extended salinity towards inland of the country. Forestry, fisheries and crop will suffer much including the mangrove forest in Sundarbans will be seriously affected. Shrimp farms and many presently grown crop varieties will either be damaged or will seriously cause to decline productivity.

The vast coastal croplands suffer from salinity related problems in the winter months. This is particularly common in nearly 1.0 mha of the present salt affected soil in the coast. Because of cyclone and storm surges, high spring tide inundation and capillary actions salt accumulate at the surface and root zones. As a result, a large area in the coastal districts is virtually unsuitable for a number of crops, while the production of other crops will yield less due to salt injury. About 0.13 Mt food grain is lost annually due to adverse impact of soil salinity.

More than one third of arable land of the country is located in the coastal area, but all of these areas are not productive due to salinity intrusion. Soil salinity is considered to be a major constraint in food grain production in the coastal areas of Bangladesh (Habibullah et al., 2001). The General Circulation Model (GCM) made a prediction that during the winter the index of aridity will increase in warmer climate (Ahmed et al., 1996 and Habibullah et al., 2001). In the dry season the soil starts to dry and due to capillary action salt comes up to the surface of the soil and accumulate in the root zone.

Due to salinity 0.2 million ton of rice production is reducing. The affect of soil salinity on Aus production would be detrimental and Aman also suffers over two-fold yield reduction when grown under a severe climate change scenario (Habibullah et al., 2001). The increase in inland penetration of salt water is another major impact of sea level rise. A rise in sea level increases the salinity of an estuary by altering the balance between fresh water and salt water hydraulic regimes. The impact would be widely felt during dry weather conditions with greater penetration of salt water. Many crops that are not salt tolerant can not grow in the coastal areas.

Soil Salinity in Coastal Region: Salinity in soils adversely affects germination of crop seeds, growth of plants and consequently yields of crops. About one-third of the country's coastal belt of 2.85 million hectares is affected to varying degrees of salinity (BARC, 1990). The BARC Task Force Report of 1998 mentioned that all the coastal districts are experiencing increasing intensity of salinity, among them Bagerhat, Satkhira, Khulna and Bhola record two to four times rise in the intensity over a period of two decades.

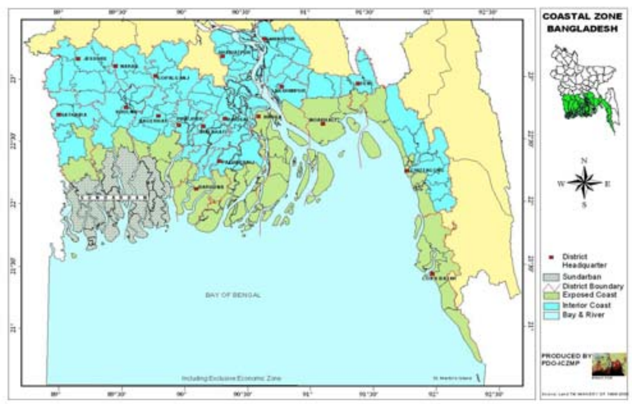


Fig 5: Coastal Zone of Bangladesh

The Sundarban mangrove forest areas also record rise in soil salinity (Hassan, 1999). The salinity rise in the south west belt has already affected cropping practices besides harming the bio-diversity in the mangrove forests (Sattar and Faizuddin, 1998). The increase is caused by intrusion of saline water into rice fields for shrimp culture. This is also due to diversion of the Ganges flows at the Farakka, (Akhter and Farooque, 1999).

Another study carried out in the mangrove forest area finds that the number of Sundri trees is falling overtime due to rise in the salinity level (Faizuddin, *et. al* 1998). According to Talukder, 1999 vegetative coverage in high saline area has gone down and for that matter green environment is going to be destroyed in the shrimp zone. Shrimp culture has also been limiting grazing ground for livestock production (BIDS, 2001). These are environmental challenges the country is going to face due to climate change overtime. The over-all view is that soil salinity in the region has overtime increased affecting the land productivity and also the mangrove forests in the Sundarban area. The existing green environment in the shrimp area in the coastal zone is thus, threatened to be destroyed if adequate protective measures are not taken against the climate change scenario.

5.3 Flood and Sidr 2007

A recent rapid study of the Ministry of Food Disaster Management reported that about 4.7 million people affected in the nine districts, more than half 2.6 million people were severely affected. They need immediate assistance for recovery and restoration of their livelihood. The report said the combined effects of August floods and the cyclone Sidr have worst disrupted agricultural production in Bangladesh. Sidr fully damaged crops of 112,879 hectare and partially damage crops of 1,399,999 ha of land. These damages resulted in a loss of production 1,295,315 metric tones of crops and these further affected 2,224,462 families in the coastal area.

Crop: Sidr inflicted serious damage to other crops besides rice; these include pulses, banana and other seasonal vegetables. The storm surge inundated huge area of crop lands with saline water that has affected the large area of standing crops and damaged the potentiality of agricultural land. Sidr may cause loss of aman production of about 1.3 million tons and also seeding of boro and rabi crops. The study estimated each ha fully damaged crops at Tk 40,000 to recover while partial damage cost was assumed to be Tk 20,000.

Another most recent study jointly by Government and World Bank (Feb, 2008) reported that as an outcome climate change the 2007 Cyclone Sidr has caused significant damage to rural infrastructure and economic assets.

The preliminary damage and loss assessment for crops, livestock, and fisheries is estimated to be Tk 30.2 billion (US$ 437.64 million), of which Tk 1.5 billion (US$ 21.33 million) is damage and Tk 28.7 billion (US$ 416.31 million) is production loss. The most important thing to note here is that the agriculture sector consists primarily of private farmers and fishermen, almost all of the damage and loss has occurred in the private sector. During preparing investment the role and fate of private farmer must be taken into account. Both the macro *and* micro socioeconomic impact of Cyclone Sidr is substantial and this can be made into four broad categories: (i) food supply (mainly rice); (ii) income and employment; (ii) availability of agricultural inputs; and (iv) prices of food and agricultural inputs. The invest plant for Sidr recovery and reconstruction deserve to have special attention to these specific areas.

GOB-World Bank joint study (2008) indicated that approximately, 2.2 million farmer families have been affected by Sidr. Almost all of the damage and loss is classified as potential production loss. The total damage and loss for the crops sub-sector is estimated at about Tk 28.4 billion (US$ 412 million). The potential production loss for all crops is estimated 1.3 million metric tons, of which 63 percent (0.8 million metric tons is aman rice). Of a total 30 affected districts, the potential production loss is accounted for by the worst-affected districts (42 per cent), the badly affected districts (44 per cent), and the moderately affected districts (14 per cent).

Livestock: The baseline survey found that in the study area about 40% of households are rearing cows and bulls, 25% of them are rearing buffaloes, 50% of them are rearing goats and 90% of them are rearing chicken and ducks. Out of that 30% cow and bullock, 15% buffalo, 15% goats and 85% chicken and duck have been damaged.

In the Sidr affected area, the death of livestock was about 106,189 cattle, goat and sheep and the poultry birds about 2527,880. Besides the death of livestock about 4884,503 cattle and 31,510,839 poultry birds in 17 Sidr affected areas had been seriously affected in terms of different diseases and loss of fodders. In addition to these about 5,934 diary and poultry farms and 19,900 MT of fodders and poultry feeds were damaged. The loss of livestock sector was estimated at Tk 12.78 million. The average unit price per buffalo /cow was assumed to be Tk 12,000 which seems to be very misery estimate; the average unit of price of others was assumed as: goat and sheep Tk 1200, duck Tk 80, chicken Tk 92, dairy farm Tk 15,000, poultry farm Tk 10000, fodder and poultry feed Tk 2000/MT. There are expenditure for vaccination, seeds, fodders, shelter and rehabilitation still remains to be estimated.

GoB-World Bank joint study (2008) also revealed that almost 80 per cent of the animals and 76 per cent of the birds died in the worst affected 4 districts. There was also damage to animal and poultry sheds (both cattle and poultry farms) and loss of feed (cattle and poultry), fodder and pasture. There was also some damage to public sector infrastructure (trees, animal sheds, and buildings). The estimated damage to the livestock (subsector) is Tk 1.3 billion (US$ 19.33 million).

Fisheries: Fisheries in 17,700 ha of land in 42 upazila in 11 coastal districts washed way during the super cyclone Sird. In the Sidr affected area around 139,478 ponds, water bodies fish and shrimp farms were heavily affected during the Sird. Besides this, equipment, machinery, fishing nets, boats are also severely affected. It is reported in the study that about 5,721 metric tons (MT) of fish, 799 MT of shrimps and about 20.53 million of fingerlings were damaged. The cost of equipment that has been damaged estimated at Tk 227.49 million. Both public and private infrastructure damage was estimated at Tk 64.97 million. A total loss has been estimated at fishery sector at TK 729.40 million.

The joint study (GoB-WB, 2008) also reported that fisheries are one of the fastest growing agricultural sub-sectors in Bangladesh that provide cheapest protein for the nation. Most of the growth is attributed to fish and shrimp aquaculture. Shrimp, in particular, thrive in the brackish waters of the coastal districts that were affected by Sidr. The damage and loss that Sidr caused consists of damage to fisheries infrastructure such as ponds, dighis, and ghers; damage to private fishing equipment such as boats and nets; and damage to public infrastructure such as boundary walls, roofs, and electric lines in fisheries- related public buildings. The damage and loss to the fisheries subsector, in the most affected 10 districts, is estimated at between Tk 463 million and Tk 692 million (US$ 6.71 million to US$ 10.03 million).

Biodiversity loss: CEGIS made an estimation and found that the impact on flora and fauna loss has been estimated 40 species of mammals, 400 species of birds, and more 200 species of fish having been destroyed. The extinct species like tiger and endangered spotted deer were also the victim of Sidr. The forest department made an estimation of loss which stands to Tk 44.24 million. This includes damaged infrastructure like office buildings, dwelling house, tourist spots and other recreational amenities.

The supper cyclone Sidr caused major destruction of natural wind breaker in the Sunderbans, which is the world largest mangrove. Approximately 30 thousand ha of forest area were almost damaged, about 70 to 80 thousand ha area are moderately damaged. The Sidr also caused casualty to the animals which includes Royal Bengal Tiger and Dotted Deer. The rescue team recovered 24 deer and 01 tiger; no injury information available. The innumerable loss of intangible benefits and services of biodiversity and other natural and environmental resources are yet to be estimated. The cost of fully damaged infrastructure as estimated by Ministry of Environment and Forest stands at Tk 166.43 million. The cost of partial damage estimated at Tk. 31.95 million.

Temperature: Temperature rise will induce higher evapo-transpiration. As such, more water will be needed for the plants and on the other hand there will be scarcity of surface and ground water. Performance of irrigation equipment will be less. So, cropland will suffer from water stress. There will be loss in crop yield as well as crop and forestry spices. Fish production will suffer due to temperature rise. With the rise in winter temperature and due to reduction in the cool water periods, many of the areas now suitable for production of different crops like wheat will be turned unsuitable or the yield will be reduced greatly. With a 4^0 C temperature rise affects the 32% decline in Boro rice production and a 31 % in wheat production (WB study 2000).

Precipitation: A 10 % increase in precipitation may increase runoff depth by one-fifth (WB study 2000). In winter, low-flow conditions in the rivers are often observed. Water demand will be more and farmers usually react to ensure irrigation by exploiting groundwater resources. Low-flow conditions cause economic hardship to the poor farmers. Precipitation will be less, and thus recharge of ground water will suffer. Due to decrease in rainfall, surface water flow will be less and there will be greater backward thrust of seawater towards inland. For this reason most of the suitable agricultural land will be turned unfertile or less productive. In summer, increasing rainfall will result in greater surface water flow and thus flooding. Due to flooding, agricultural production loss will be more pronounced. Flood of 1998 resulted in a loss of over 50% of the standing crops.

Rainfall: Summer rainfall will increase by 11% and winter rainfall will decrease by 3% by the year 2030 (World Bank, 2000). It is predicted in the same study that by the year 2050, sea level rise will be 50 cm, when summer rainfall will increase by 28% and winter rainfall will decrease by 37%. Due to drainage congestion and inundation with saline seawater, degradation of land quality will further worsen. Soil fertility will decline because of changing physical and chemical characteristics and accumulation of salts on the surface. As regards irrigation water, over supply and under supply of surface water in different seasons and greater contamination of ground water by arsenic and other heavy metals, would result disruption of ground water use for irrigation purposes. Due to climate change, coastal ecosystem and bio-diversity including the presently suitable germsplasm will also suffer.

Drought: Agricultural drought refers to a condition when the moisture availability at the root zone is less than adequate. This is how; Aman cultivation suffers from periodic drought conditions during Kharif II season. Similar conditions are often observed in early pre-Kharif period; affecting Boro and in Rabi season, wheat cultivation in the northeast and central-east regions of the country. Dry season drought affects the production of wheat, potato, mustard and Aus Paddy (Karim et. al., 1990) Drought-related vulnerability and its impact may be counteracted either by supplementary irrigation for the Kharif or ensured irrigation for the Rabi and pre-Kharif crops. Drought normally affects about 2.3 Mha of cropland during April to September (Kharif season) and 1.2 Mha in the dry season (October to March). Drought during Kharif severely affects the transplanted Aman rice incurring annual production loss by about 1.5 Mt of rice.

In winter months the western parts of Bangladesh are periodically affected by droughts. Since the temperature will rise there is a strong possibility of decreasing the winter precipitation. Higher temperature would induce higher rates of evapo-transpiration. Consequently, late Kharif-II drought in December affects Aman crop at the ripening stage, Rabi drought affects wheat and Boro crops at both germination and vegetative growth rate. In early Kharif-I affects the Aus production significantly.

Sedimentation: The influence of sedimentation on the total agricultural areas is expected to be disturbed by the climate change. There is an expert opinion that deposition of sedimentation's range is 0.5-1.8 billion ton per year. Average accretion in Bangladesh is close to one thousand hectares per year, which needs about 15 years to develop for agricultural production purpose. At the same time erosion causes loss of valuable land sometimes with agricultural products. The cost of the loss for the economy needs to be estimated.

The monsoon river currents also some times erode river banks, and wash away fertile land from the adjoining plots. In this connection a study on the basis of landsat image analysis reports that in a decade almost 87,000 ha of land is lost due to bankline erosion, more than 50% of which is along the Brahmaputra-Jamuna bankline. On average, loss of land along the Brahmaputra-Jamuna bankline is about 8700 ha per year (ISPAN, 1993), resulting in annual loss of rice amounting to US $ 1.7 million. Study also indicates that during the period of 1981-92/93, on average 64,000 people are displaced every year; most of them later migrate to urban centers (BIDS 2001).

The SRDI estimates total annual soil loss of 1.44 million tons or equivalent to US $ 1.8 million a year in the whole hilly regions where Jhum cultivation of rice in high hills shares 60% and the remaining 40% is due to cultivation of arum, ginger, turmeric, pineapple etc

Damage and Loss for Sunderbans

The Sunderbans, is the largest mangrove ecosystem of the world. The Sunderbans are known for its wide range of flora, fauna and aquatic life. Sidr struck the eastern part of the Sunderbans, especially Dublar Char, Kotka, Kochikhali, Hiron Point, Sharankhola, and the Chandpai area, causing severe damage within 300 m of riverbanks. Satellite imagery reveals that the cyclone covered about 30% of the Sunderbans. The severe ecosystem disruption included uprooted, broken and twisted plants, and burnt foliage. The Forest Department estimated that about 30,000 acres of forest resources were severely affected and another 80,000 acres were partially affected. The FD estimated total forest resources damaged in the affected 110,000 ha are about Tk 10 billion (US$ 145 million).

The joint study (GoB-WB,2008) indicated that the monitoring and surveillance facilities of the Forest Department have been severely damaged, including many old, outdated infrastructure facilities and boats the Forest Department uses to patrol and monitor the area. All ninety-four administrative units were severely affected with nearly all of the offices and residential buildings in the eastern of Sunderbans demolished or damaged. Twenty communication towers and RT sets were damaged severely, seriously disrupting communications. Fifty boats were destroyed and nine others damaged, hampering the mobility of staff posted in remote areas. FD estimated damage to infrastructure and watercrafts at about Tk 200 million (US$ 2.9 million).

The importance of Sunderbans coastal forests as a natural barrier to reduce wind velocities (protecting embankments and settlements) was enormous. Many coastal forests were heavily damaged by the uprooting of millions of timber and fruit trees, nurseries were destroyed, and hundreds of miles of roads and embankments with planted trees on the slopes were eroded.

The estimated damage, including damaged infrastructure, is Tk 100 million (US$ 1.4 million). In addition, the FD estimated the damage to areas under social forestry programs at Tk 120 million (US$ 1.7 million). The physical damage includes 3362 miles of strip plantation, 78 ha of char land plantation and nursery seedlings.

Total damages, estimated by the FD, includes Infrastructure and Watercrafts (Fully destroyed) worth Tk. 200.0 million for reserve forest, damage to forest resources coastal afforestation region indicated about Tk 83.0 million infrastucture and others cost about Tk 16.97 million. The damage to social forestry in Sunderbans area is worth Tk 120 million.

6.0 Climate Change and Agriculture

The country has about 8.5 mha of cultivable land of which 7.85 mha is under agriculture where the net cultivable area 37% is single cropped, 50% double cropped and 13% triple cropped. The cropping intensity is 176%. Three cropping seasons coincide with the three meteorological seasons: Kharif I (pre-monsoon), Kharif II (monsoon) and Rabi (winter or dry). Aus, Aman and Boro are the rice grown respectively in these 3 seasons. Aman is the leading rice crop, occupying about 56% of total rice areas followed by boro (27%) and Aus (17%). Due to double or triple cropping, the total cropped area amounted to about 17 mha. Since 1986-87, the cropping intensity is gradually increasing from 150% to 176%. In 2000-01 annual production of rice was 25 million tons where 1.6 million tons of wheat was produced (BBS, 2002) and thus Bangladesh tends to the level of self-sufficiency.

Bangladeshi farmers have little mechanized agricultural tools. There were 5,300 tractors in Bangladesh whereas Pakistan with about twice the area for agriculture had more than 54 times the number of tractors in the early 1990 (WRI 1998). Farmers are quite poor and the size of farmer is very small for continuous utilization of land. For various kinds of development activities and different types of disaster nearly 1% of the cultivable land is lost every year. Sustainability of food production is however, a big question, because of risk factors in agriculture and the predicted change in climate.

The potential effects of climate change in Bangladesh are considered for the period from the present to 2050. Most development projects of Bangladesh have a planning horizon of 30 years or less, while a few have a planning horizon of 50 years or slightly more. Results on potential impacts by 2030 and 2050 are qualitatively summarized below. Analysis of changes in climate is based on model outputs for creating climate change scenarios. The climate change impact studies have been based on the climate change scenarios developed for 2030 and 2050 as produced by Table 1.

The climate change scenarios for 2030 and 2050 have been found using general based on circulation models (GCM) results superimposed on long-term climate patterns over ten locations in Bangladesh (World Bank 2000). The study by Khan et. al. (1999) has shown that the mean tidal level at Hiron Point in the west coast of Bangladesh has been rising at the rate 4 mm/per year during the last two decades (1977-1998). The rise of mean tidal levels at the Meghna estuary (Char Chenga) and at Cox's Bazar are 6.0 and 7.8 mm per year respectively. This rise may be due to thermal expansion of the sea, geological subsidence and other reasons like intensification of monsoon winds and higher runoff from the landside. This shows that the relative sea level rise in Bangladesh coast is highly prominent, however, since the data length is short, it might not reflect the exact nature of the long-term change of mean sea level. It may be mentioned here that the average sea level rise for Indian coast has been reported as 2.5 mm/year since the 1950s (climate change in India 2001, http://www.ccasia.teri.res.in/country/india/india.htm).

Asaduzzaman, 1996 also attempted to estimate losses due to land degradation following the regression analysis. He estimated total loss of outputs to the extent of 1.73 to 4.38 million tons in 1991 valuing Tk. 1833 to 4644 million or US $ 44 to 110 million (@ Tk. 42 per US $). His estimates of production loss amount to 15-30 per cent of the BARC's figure (Table 4). According to his estimate degradation due to forestry is tremendous, its gross value of loss being Tk. 4408 million.

Table 4: Provisional estimated cost of land degradation in Bangladesh

Type of degradation	Quantity of lost output (million ton/yr)	Quantity of loss as Addl. input (million ton/yr)	Cost in million US $/yr
Water Erosion	Cereal prods.loss = 1.06 Nutrient loss = 1.44	-	140.72 544.18
Fertility Decline	Cereal prods. loss = 4.27	- Addl. inputs = 1,22	566.84 461.04
Salinization	Total prod. loss = 4.42	-	586.75
Acidification	Total prod. loss = 0.9	-	119.47

Source: BARC, 1998.

6.1 Land Degradation: Production Loss of Paddy in the Country

Two studies have been conducted for estimating production loss of paddy in two ways. One estimation is based on the results of randomly selected plot survey and the other one according to the findings of the most deteriorating plots (Table 5) considering degradation of land to the extent of one-fourth of Aman and Boro production as concluded from earlier analysis. HYV-Aus has been left out as its yield remains unchanged over time.

Table 5: Production loss of paddy under two scenarios

Rice	Yield	First scenario (Random plots)		Second scenario (Deteriorating plots)		
		Estimated yield decline-rice + equivalent (%)	Production loss (million tons in 1999)	Area most Deteriorated (%)	Estimated yield decline in rice equivalent (%)	Production loss (million tons)
T. Aman	9.0	11	1.0	25	24	0.54
Boro-HYV	10.0	7	0.7	25	29	0.72
Total	19.0	9	1.7	25	7	1.26

Note: Rice equivalent is taken to be 67% of paddy.
Source: Estimated by Quashem 2002.

The random plot survey estimation found a production loss of 1.7 million tons of rice; whereas the second method based on the deteriorating plots finds the loss of about 1.3 million ton or roughly it can be taken to be 1.5 million ton or 8% of the country's recent production of Aman and Boro production. Total loss of rice amounts to US $ 300 million @ US $ 200 per ton of rice. This is of course much lower than the earlier estimates made by BARC as the present study includes only rice ignoring all other crops and the loss due to costs of production inputs like fertilizer, irrigation etc. but it is nearer to Asaduzzaman's estimates. Any way, we may conclude that annual loss of rice from land degradation is substantial.

The exercise estimates annual loss of top soil to the extent of 1.36 million tons from 33,237 ha of cultivable land in the hill tracts. Soil losses cause depletion of plant nutrients like Nitrogen, Phosphate, Potash, Calcium, Magnesium etc. which can be replenish with chemical fertilizers such as urea, TSP and MP amount to 14,048 tons per year costing about US$ 1.8 million, required to procure such fertilizers.

Table 6: Different types of land degradation and their extent in Bangladesh

	Areas (in mha) affected by different degrees of degradation				Total
	Light	Moderate	Strong	Extreme	
Water erosion	0.1	0.3	1.3	-	1.7
- Bank erosion	-	1.7	-	-	1.7
Wind erosion	-	-	-	-	-
Soil fertility decline	3.8	4.2	-	-	8.0
-3 P deficient (for HYV rice)	5.3	3.2	-		8.5
-4 P deficient (for Upland crops)	3.1	2.5	-	-	5.6
-5 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	4.05		8.7
Soil organic matter depletion	1.94	1.56			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
Lowering of water table	-	-	-	-	-
Active floord palin	-	-	-	-	1.53
Deforestation	-	0.3	-	-	0.3
Barind	-	-	-	-	0.773

The estimates of the extent of land degradation in Bangladesh are that over 6.0 million ha falls below the minimum threshold for sustainable cultivation. In drier parts of Bangladesh, low soil fertility is recognized to be at the root of the land degradation spiral leading to desertification. Land degradation in Bangladesh may be considered as temporary or permanent lowering of the productive capacity of land. Natural processes that lead to land degradation in Bangladesh can be considered part of the ongoing land formation process. During 1983-84 and 1997 period, an 11% decline in total cultivable area, and specifically a 14% decline in cultivated area, has been observed.

Further evidence of land degradation is shown on satellite imagery which indicates a definite change in vegetation cover and soil moisture through many of the western regions of Bangladesh including Rajshahi, Kushtia, northwestern Jessore, Pabna, western Bogra and southern Dinajpur. These affected areas are known as the Barind Tract, a largely monocultural area with shrinking wetlands, notably the Chalan Beel wetlands. Human intervention from densely populated adjoining regions (around the national average of 900 persons per km^2) makes these areas vulnerable.

The land degradation deals with causes of land degradation, both in terms of deterioration of soil quality and loss of land and its productivity causing economic loss to the nation. 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.

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 practices, absence of a land use policy, and ineffective implementation of existing laws, policies 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 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..

Land Ownership and Tenure: The existing 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 farm owners almost in all cases retain the irrigable lands (even if they cannot manage them all by themselves) and lease out the relatively less productive, non-irrigable land. The irrational 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. It has serious implication of incurring economic loss in the future for the economy.

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 settings, 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. 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.

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 compel 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. 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. This needs attention for addressing the issue of climate change in order to recover the economic loss of the country.

About 6.0 M ha, or 43% of the total geographical area is affected by various forms and degree of degradation. About one fourth of the total cultivable land is affected by drought in every year with different intensity. The recovery of such land depends upon its resilience, which, however, may be lost completely if the land is not treated in time with care.

Frequent droughts, through its short-lived but recurrent stress, can aggravate the adverse impact and, if not checked properly, can interfere with the natural capacity of land to recover and advance the process of desertification. Agricultural intensification and the increase in irrigated area have led to a number of environmental problems i.e., loss of bio-diversity through the conversion of forest land into agricultural land; abandonment of many indigenous crop varieties in favour of HYV's leading to irreversible loss of the country's genetic resources; depletion of soil nutrients and organic matter due to intensive cropping; and deprivation of soil from organic content due to use of crop residue as fuel.

Table 7: 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: Bangladesh: State of the Environment 2001

Table 8: Summary of estimates of the cost of land degradation in Bangladesh

Nature of degradation	Physical quantity of lost output in MT/yr	Tk equivalent/ yr (million)	Cost (million) US$/yr	Remarks
Water erosion	Cereal production loss = 1.06	6613.84	140.72	
	Nutrient loss = 1.44	25576.46	544.18	
Fertility decline	Cereal production loss = 4.27	26641.48	566.84	
	Addl. Inputs = 1.22	21668.88	461.04	
Salinization	Total production loss = 4.42	27577.25	586.75	
Acidification	Total production loss = 0.09	561.51	11.95	
Lowering of water table and water logging	-	-		Not assessed

Source: Bangladesh: State of the Environment 2001, MoEF

Other environmental degradation includes loss of wetland habitats through abstraction and drainage resulting in depletion of aquatic fauna and flora and reduction in water availability to the rural population, increased use of agro-chemicals raising the pollution potentials of surface and ground water.

Table 9: Land Utilization

Area in Thousand Acre

Year	Forest Area	Cropped Area	Total Area
1986-87	4910	34883	36669
1996-97	5329	34089	
2003-04	6418	35129	

Source: Bangladesh: State of the Environment 2001

Soil Erosion: Soil erosion is a persistent problem in many parts of Bangladesh. The main reason for erosion are: river bank erosion due to flooding, sheet erosion on agricultural land due to irrigation, soil losses due to wind in dry season (north part), soil erosion in hilly areas (Chittagong, Comilla, Sylhet, Gazipur) by landslide due to hill cutting, soil exploration (Netrakona, Mymensingh) for industry like white clay. It is difficult to get the actual soil erosion data. However, Soil Resources Development Institute provided the total areas which are given below in Table 10.

Table 10: Soil Erosion in Bangladesh

Area	Moderate Susceptitibility to erosion	High Susceptitibility to erosion	Very high Susceptitibility to erosion	Total
Chittagong Hill Tracts	350	1,814	10,765	12,929
Chittagong & Cox's Bazar	414	949	954	2,317
Greater Sylhet	161	462	964	1,587
Comilla, Brahmanbaria, Netrakona, Jamalpur		35	102	137
Total	**925**	**3,260**	**12,785**	**16,970**
% of Total	5	20	75	100

Source: Bangladesh: State of the Environment 2001

Erosion in the coastal zone: The natural shape of Bangladesh coastal and marine areas are controlled by dynamical processes such as tides, wave action, strong wind and sea level variations. Land erosion is a common natural phenomenon in the coastal zone (PDO-ICZMP 2004b). Massive changes have occurred in the coastline over the last two centuries due to land erosion, coupled with land accretion. Erosion is most severe in the Meghna estuary. A huge land of 86,366 ha eroded during 1973-2000 (MES 2001). Strong tidal currents and storm generated swell in association with sea level rise may cause coastal erosion, irregular inundation and flooding. Sea swell may cause coastal erosion, depending on the height and periodicity of swell wave. Coastal erosion usually occurs during monsoon seasons, but it is more severe during southwest monsoon or any episodic events such as storm waves or sea swell hit the coast. Besides the erosion of the riverbanks, the foreshore and the embankment systems are posing a continuous problem in the coastal areas. This exposes interior lands to the threats of cyclone surges and salt-water intrusion (PDO-ICZMP 2004b).

Desertification and salinization: Withdrawal of waters from the rivers due to irrigation purposes and diversion of waters from upstream is the main cause of increasing salinization. Fall of surface water is also partly responsible for depletion of water level and as a result, process of desertification threatens northern part of Bangladesh and increase of salinity occurs in southern part of Bangladesh.

Table 11: Distribution & extent of soil salinity in the coastal and offshore areas of Bangladesh

District	S1 2-4 ds/m	S2 4-8 ds/m	S3 8-16 ds/m	S4 >16 ds/m	Total
Khulna	28.83	37.32	59.49	19.61	145.25
Bagerhat	35.66	41.50	41.23	6.74	125.03
Satkhira	27.03	38.01	60.03	22.01	147.08
Jessore	7.21	3.06	0.59	0.00	10.86
Narail	10.67	4.30	1.08	0.00	16.05
Perojpur	19.06	6.05	2.43	0.00	28.61
Jhalakati	2.35	1.17	0.00	0.00	3.52
Barisal	8.12	2.70	0.55	0.00	10.82
Bhola	28.44	33.70	26.13	5.27	93.64
Patuakhali	40.11	43.62	46.10	9.52	139.53
Barguna	36.22	30.77	33.47	3.77	104.23
Gopalgonj	5.76	3.12	1.32	0.00	10.20
Madaripur	0.79	0.40	0.00	0.00	1.19
Laxmipur	8.55	6.10	2.93	0.00	17.58
Feni	2.61	4.20	0.40	0.00	7.30
Noakhali	13.04	16.93	15.83	7.75	53.55
Chittagong	12.38	22.08	10.07	1.97	46.50
Cox's Bazar	2.83	11.08	35.55	10.50	59.96
Country Total	**289.76**	**306.20**	**337.20**	**87.14**	**1020.75**

Source: SOE, 2001

Drought: Past droughts have typically affected about 47 per cent area of the country and 53 per cent of the population (Task Force, 1991). A geographical distribution of drought prone areas under climate change scenarios shows that the western parts of the country will be at greater risk of droughts, during both the Kharif (January – May) and post-Kharif (June – October) seasons. It is found that, under a moderate climate change scenario, Aus production would decline by 27 per cent while wheat production would reduce to 61 per cent (Karim et al., 1998). Under a severe climate change scenario (with 60 per cent moisture stress), yield of Boro might reduce by 55-62 per cent. Moisture stress might force farmers to reduce the area for Boro cultivation.

In case of a severe drought, forced by a change of temperature by +2^{o}C and a reduction in precipitation by 10 per cent, runoff in the Ganges, the Brahmaputra, and the Meghna rivers would be reduced by 32, 25 and 17 per cent respectively (Mirza and Dixit, 1997). This would limit surface irrigation potential in the drought-vulnerable areas, and challenge food self-sufficiency programs of the country. The northern part of Bangladesh is more prone to drought than other areas of the country. The historical pattern of droughts in Bangladesh is given in the following Table 12.

Table 12: Droughts in Bangladesh

Year	Percent of land affected	Percent of population affected
1950	13.70	14.13
1951	31.63	31.51
1957	46.54	53.03
1961	22.39	20.76
1966	18.52	16.54
1972	42.48	43.05
1979	42.04	43.90

Source: Bangladesh Meteorological Department and Khan, 1993

6.2 Impact of Climate Change on Agriculture

The models for HYV rice and wheat production for the entire country have been carried out. The observations are discussed as follow:

HYV Aus Rice: The average production of HYV Aus rice in Bangladesh was 798 thousands tons during 1999-2000 (BBS 2001). The production reduced by 27% under CCCM and GFDL3 scenarios. The production will increase by 31% and 40% respectively when the CO_2 levels will increase to 580 and 660 ppmv without any temperature rise. Rise of temperature by 2^oC at 330 ppmv CO_2 results in 19% reduction in production level. While, 2^0C temperature rise at 580 and 660 ppmv CO_2 will increase the production by 13% and 22%. Further increase in temperature to 4^oC at 330 and 580 ppmv CO_2 levels will reduce the production by 38% and 6%; respectively, but increase the production by only 4% at 660 ppmv CO_2 level (USCSP 1996). For HYV Aman Rice, HYV Boro rice and wheat production under different climate change scenarios are given in the Table-13.

Table 13: Aggregated Rice and Wheat Production under Different Climate Change Scenarios

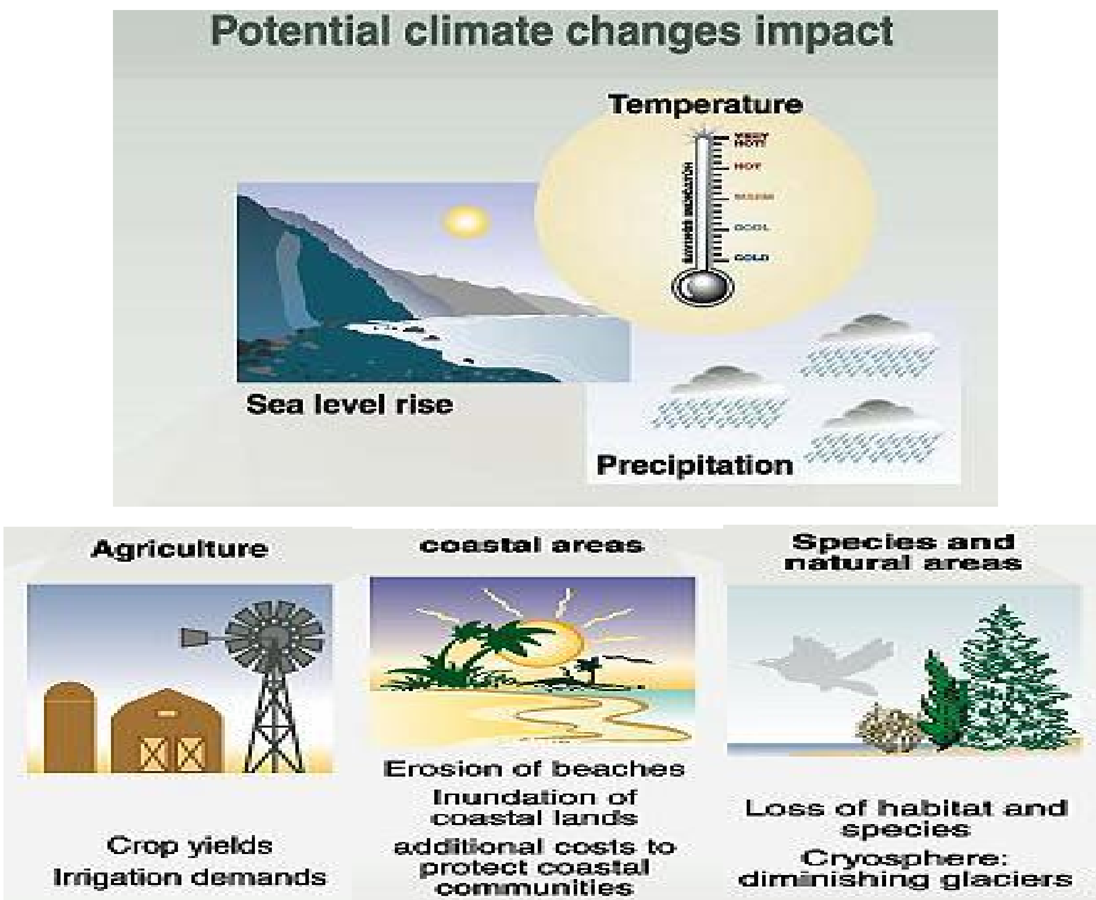
Simulation	HYV Aus		HYV Aman		HYV Boro		Wheat	
	('000' tonnes)	Per cent Change	('000') tonnes	Per cent Change	('000' tonnes)	Per cent Change	('000' tonnes)	Per cent Change
Baseline (1999-2000)	798	0	3,246	0	10,671	0	1840	0
CCCM	582.54	-27	3,019	-7	10,351	-3	1472	-20
GFDL	582.54	-27	2,824	-13	9,924	-7	717.6	-61
330 ppmv CO_2 +2°C	646.38	-19	2,824	-13	10,244	-4	1159.2	-37
330 ppmv CO_2 +4°C	494.76	-38	2,435	-25	9,924	-7	588.8	-68
580 ppmv CO_2 +0°C	1045.38	**31**	4,058	**25**	13,125	**23**	2539.2	**38**
580 ppmv CO_2 +2°C	901.74	13	3,603	11	12,805	20	1821.6	-1
580 ppmv CO_2 +4°C	750.12	-6	3,278	1	12,378	16	1104	-40
660 ppmv CO_2 +0°C	1117.2	40	4,317	33	13,872	30	2723.2	48
660 ppmv CO_2 +2°C	973.56	22	3,863	19	13,552	27	2005.6	9
660 ppmv CO_2 +4°C	829.92	4	3,538	9	13,125	23	1269.6	-31

Source: Adapted from USCSP, 1996.

6.3 Threats ahead on Agriculture

There are four factors responsible causing changes in the greenhouse world that eventually influence plants behavior and productivity. These are carbon assimilating capacity of crops, water availability in the soil, and temperature of weather and intensity of light. Rice plants are more capable than any other plants to assimilate carbon. The increases in the temperature rather have various negative effects and similar effect may also prevail in case of fall in light intensity. The increase in temperature will probably mean somewhat extension of the period for aman growing (main rice crop) which is thermo sensitive. Thus it is very difficult to speculate the magnitude and the move of the rice production with the given current state of knowledge. But with given doubling of carbon dioxide concentration in the atmosphere, one possibly expects a 5 percent increase in agricultural yields (ADB 1994).

The realization of the potentiality is also depends on natural and economic factors. The ADB (1994) study revealed that 10% increase in agricultural potential will cause to increase simulated yield of only 4.3%. But the agriculture has to come across much of the problems due to changes in the coastal zone, especially the potential sea level rise.



7.0 Valuation of Environmental Impact

Considering the future challenges of climate change, risk, threat of disaster and natural calamities, prior to undertaking a project, the first task would be identifying and measuring the environmental impacts that are often dislocated in times and space making cause and effects. There is glaring example of 2007 two frequent floods and Sidr were never considered in the development planning design. These natural catastrophes made the economy shattered and vulnerable. Thus urgent attention is needed to put the climate change risk factors to be integrated in planning process and as far as possible monetized these and keep budgetary provision in order to cope with future risk factors.

It is very difficult to identify the impact and measure them properly over time and space. Besides, many environmental goods and services do not have market price doing so only imperfectly. Moreover, non-availability of data (and /or poor quality of information) in the developing countries like Bangladesh are not reflecting the real picture of the environmental impact. In undertaking an economic analysis the important things to be taken care of include: (i) the economic analysis that normally consist of estimating monetary costs and benefits (valuation) of the various environmental impacts identified in the EA, using a range of *valuation* techniques: (ii) the analysis is extended to consider the costs and benefits of preventive and mitigation measures for comparison with the original project impacts; (iii) the monetary values for the selected alternative towards integrating into the overall economic *evaluation* of the project to be undertaken.

7.1 A Review on the Economic Concept of Environmental Value

There are various interpretations of the term “environmental value”, economists have primarily concentrated on monetary value, as expressed via stated or revealed individual preferences.

Pearce and Turner (1990) synthesized that economic value is not an intrinsic quality of anything: it only occurs because of the interaction between a subject and an object. It follows also environmental attributes that have value when they enter at least one individual’s utility function or a firm’s production function. Attributes failing either of these criteria have no economic value (Hanley and Spash, 1993).

The main rationale behind measuring, in monetary terms, the costs (or benefits) of environmental (quantity or quality) changes, is to the translation of individual preferences into monetary values is generally interpreted and recommended as an operational device for ex ante valuation (“cost-benefit analysis”) of alternative courses of action entailing both expected environmental changes and alterations in the allocation patterns of other economic goods. Or to evaluate (ex post) the welfare impacts of actual environmental changes, in order to determine compensable damages or to assess the economic efficiency of restoration measures.

There are many advanced operational monetary valuation methods in place, but many writers have questioned or strongly criticized the preference-related value theory underlying economic valuation and valuation techniques.

Many economists/scientists alleged that the economic theory is based on a very narrow and simple definition of self-interest and by so doing, it fails “to describe the environmental values people hold, the process of value construction or the way individual values are aggregated into a social value” (Brouwer, 2000, p.138). Moreover, “eco-centric ideologies place primary emphasis on a distinction between instrumental value (expressed via human-held values) and intrinsic, non-preference-related value. They lay particular stress on the argument that functions and potentials of ecosystems themselves are a rich source of intrinsic value. This value would, it is argued, exist even if humans and their experiences were extinct” (Pearce and Turner, 1990, p.22).

Pearce and Turner (1990) noted that the preference-related and the intrinsic-value distinction is not clear-cut. Individuals may capture part of the intrinsic value in their preferences, e.g. valuing “on behalf of” other species. Economists use the term “existence value” to encompass these notions. Similarly, the economic concept of “bequest value” is used to encompass intergenerational equity concerns.

Willingness-to-pay and willingness-to-accept: Environmental values are measured in money terms through the concept of individuals' willingness to pay (WTP) or willingness to accept (WT A) compensation for alterations in environmental conditions.

Of these two, the WTP approach has become the most frequently applied, whilst WT A empirical studies are relatively rare. WTP is measured directly, by asking people to state a WTP amount, or indirectly, by assuming that this amount can be inferred by looking at the economic costs afforded to enjoy environmental services or at the costs incurred to acquire service substitutes.

However one of the earliest findings of stated preference studies was that WTP and WT A measures may differ radically and cognitive psychologists have proposed theories explaining the substantial observed differences (Carson and Mitchell, 1993).

An economist, Michael Hanemann (1991), has shown that the wedge between WTP and WTA can be large. The difference between the Willig’s and Hanemann’s theoretical findings is due to the fact that whilst the former focused on the welfare impacts of a price change in a perfectly competitive market, the latter considered imposed quantity changes.

Carson *et al.* (2000) argued that since changes in environmental conditions *(e.g.* natural resources damages) tend to fall into the category of imposed quantity changes, the difference between WTP and WT A measures can be very large. Nevertheless, the WTP approach has become the most frequently applied in empirical studies, and this is primarily attributable to the valuation techniques' intrinsic inability to provide reliable WT A estimates (Desvousges *et al.,* 1998; Brouwer, 2000).

Nowadays there is a broad consensus among economists about the desirable (the theoretically appropriate) welfare measure and the possible price paid -in terms of value assessment reliability- by using WTP instead of WT A estimates.

Firstly, if property rights in environmental goods and services are held by (are conventionally assigned to) people experiencing the effects of environmental changes, WT A would be the appropriate welfare measure instead of WTP (Desvousges *et al.,* 1998). This implies that the assignment of property rights "can have a substantial influence on the magnitude of the welfare measure [and] particularly when considering a reduction in an environmental service, the common practice of substituting a WTP estimate for the desired WT A measure can result in a substantial underestimate" (Carson *et al.,* 2000, p.2l).

Secondly, the more unique the natural resource under consideration, the less close the WTP estimate is to the desired WT A measure, and the more substantial the underestimation of welfare changes.

7.2 Types of Environmental Values

Use and non-use values: Following the anthropocentric approach predominantly adopted in the economics literature, natural resources may then be described as assets ("natural capital") the value of which stems from their service flows and their contribution to people's welfare. This contribution may take on different forms. Understanding how people get utility from natural resources, i.e. why they may hold environmental values, and how alterations in conditions influence these values, are key elements to economic valuation and impact assessment.

When considering why individuals place values on a natural resource, a typical approach in the literature is to distinguish between those who use the resource's (services), and those who do not (Freeman, 1993). The values held by the former group are generally termed use values, and may occur in many different ways.

Direct use values may derive from "consumptive uses" *(e.g.* fuel wood collection) and/or "non-consumptive uses" *(e.g.* hiking in the same forest), and may involve commercial (selling fuel wood or collecting visiting tolls) and/or non-commercial activities (home consumption of fuel wood or enjoyment of an open-access wilderness area).

Although the physical proximity is normally thought as being an essential part of use, some authors have argued that some kinds of "use" do not require the physical contact with the resource.

Randall and Stoll (1983), for example, have argued that there can be offsite uses, which they label as "vicarious consumption": *e.g.,* people can draw utility by looking in a magazine at pictures of a tropical forest. This is what has also been sometimes referred to as indirect use value (Boyle and Bishop, 1987), although the latter term is more frequently and meaningfully used to describe another category of values generated by natural assets.

Indirect use values, also known as functional values, derive from "the natural interaction between different ecological systems and processes; in particular, the ecological functioning of one ecosystem may affect the functioning and productivity of an adjacent system that is being exploited economically" (Barbier, 1998, p.5). More generally speaking, indirect use values may be described as the benefits individuals experience, indirectly, as a consequence of the primary ecological function of a given resource (Torras, 2000). For example, the indirect use value of a wetland may arise from its contribution to filtering water exploited by down streamer users (World Bank, 1998); forests may provide different 0 -site benefits, such as defense against soil erosion, flood control, or carbon sequestration; coastal wetlands may contribute to the protection of properties and economic activities against hurricane wind damages (Farber, 1987); and the use-value of a mangrove system may derive from its indirect support, as a breeding ground, for an offshore fishery (Barbier and Strand, 1998).

Besides use-values, it is largely agreed -or, at least, it is largely agreed by economists working in the field of environmental economics- that natural resources may also generate values which are unrelated to any actual, direct or indirect, use. So called **non-use values** "do not involve any observable behavior; they are simply experienced "psychically". Consequently, nonuse values cannot be observed by market purchases or inferred through actions" (Desvousges, 1995, p.4).

Non-use values, undoubtedly the most elusive component of a natural resource's total economic value, are said to arise from the psychological benefits people may derive from the mere knowledge the resource exists *(existence value),* or from the desire to preserve natural capital in order to pass it to future generations *(bequest value).*

Moreover, available taxonomies often include o*ption value* among non-use values. Option value may be defined as the benefits derived by an individual from preserving options for use of a particular resource when the individual is either uncertain about future use or faces uncertainty about the availability of that resource in the future.

Although the distinction between use (or user) and non-use(r) values remains the predominant taxonomy, other classifications have been suggested in order to decompose the total value of a natural resource. This to encompass the variety of terms used in the literature to describe values not arising from resources' present uses as well as to avoid frequent conceptual overlaps between some non-use and use values' sub-categories. One of these alternative taxonomies is that which simply decomposes the total value into "direct use" and "passive use" value. Following Carson *et al.* (2000), "direct use can be most easily thought of as requiring the agent to physically experience the commodity in some fashion" (p.3). Any other benefits not requiring this direct contact can be labeled as passive use value.

Although the *in situ* presence -the "physical contact" to the resource under consideration- may constitute an useful classification rule, another criterion may prove to be even more useful. This criterion derives from focusing on *whether or not individuals need to carry out an activity -entailing the use of other (marketed or unmarketable) economic goods- in order to get utility from a natural asset.*

The main advantage of this general classification criterion is that it probably allows a better understanding of the linkage between environmental values and valuation methodoloies. In fact, as it will be better illustrated later on, the various methods developed to measure these values can be classified according to the way in which the values people attach to natural resources are assessed.

In particular, a group of methods tries to infer resource values by examining the purchases of related goods in the market place. In general, these related goods are factor inputs in the consumption (or production) activity required to get utility from a natural asset, or required to compensate environmental changes, in order to preserve the same level of utility (output).

Alternatively, other valuation methods do not rely upon information about individuals' purchases of natural resources' complementary, or substitute, goods, and try to measure the resources' value by directly asking people to state how much they are willing to pay to avoid (to undertake) negative (positive) environmental changes. These expressed preference methods are typically, although not exclusively, employed when analysts believe that the resource's total value would be severely undermined by (only) looking at the utility the individuals get from carrying out activities involving the use of other economic goods.

7.3 Types of environmental services

So far mainly focused has been made on the distinction between values deriving from using natural assets (' services), and assets' values which are independent of present or expected use. We have also argued that, from a valuation perspective, the presence or the absence of activities entailing the use of other economic goods may prove useful to draw an operational borderline between environmental services underlying use and non-use values. The reference to the presence of an economic activity would imply that the "physical contact" is not necessary condition to infer a resource's use value, as long as individuals get off-site benefits from it through carrying out activities involving other economic goods.

Obviously, a natural asset may generate both non-use and (direct or indirect) use values. In particular, whilst nonusers can hold only nonuser values, users may hold both non-use and use values (Freeman, 1993). Moreover, as far as the latter are concerned, it may be useful to make a distinction between natural assets which support only one economic activity *(single use* resources) and assets which may (simultaneously) support many different activities *(multiple use* resources).

Besides the use/non-use distinction, and the single/multiple use one, an additional classification criteria also appears to be very useful when trying to assess the total value of a natural asset. We refer to the distinction between public environmental services and private environmental services.

Pure public services are those benefits flowing from a natural asset which can be enjoyed by one individual without detracting from the enjoyment opportunities still available to others (non- rivalry or indivisibility of benefits), and which cannot be withheld, at a reasonable cost, by the "owner" of the natural asset under consideration (non-excludability of benefits). On the contrary, excludable environmental services which cannot be enjoyed by one individual without affecting the other individuals' enjoyment opportunities (from the same unit of service) are labeled pure private ones.

In between points along the spectrum of fully non rival/rival and costly/costless excludable .services are called quasi-public/private goods. The latter term is used to encompass environmental services whose enjoyment by one additional individual does not affect others' enjoyment up to a point, but beyond that point congestion -which may be interpreted as a "public bad"- reduces the enjoyment of all existing and potential beneficiaries; and/or services whose enjoyment can be technically controlled, but this control is not exerted because of the lack of well-defined property rights or the high costs of exclusion.

As stated before, a natural asset may entail both non-use and (single or multiple, direct or indirect) use values, and the asset's services, underlying these values, may be often placed along the private/public good spectrum.

Whilst environmental services underlying existence or bequest values are, almost by definition, public goods, those underlying use values often hold private or quasi-private/private features. However, some services underlying direct use *(e.g.* visual amenity benefits) or indirect use (flood control) values may display both non-rivalry and non-excludability, and may be labeled as pure public ones.

Various implications stem from environmental services' private, public (or the combination of private/public) features. From a valuation perspective, the main consequence is that whilst private goods are marketable, goods holding public features are not exchanged in "normal markets". It follows that whilst observable market prices provide useful-and sometimes sufficient-information for assessing the value of private environmental services, the social benefits arising from public environmental services cannot be directly deduced by market prices, and alternative approaches have to be adopted to infer their economic value.

7.4 Valuation Approaches

There are various techniques which have been developed to measure natural assets' values in order to assess the economic impacts resulting from alterations of conditions influencing the flow of goods and services these assets provide. Broadly speaking, these techniques can be grouped into three major valuation approaches.

The first one consists of exploiting the existence of a market price for an environmental good, in order to assess its economic value. If the observable prices are not distorted, then the economic value of (marginal) environmental changes can be valued by directly using existing market prices. Obviously, if the natural resource of interest provides multiple goods and services, some (many, or even all) of which are unmarketable, this valuation approach would fail to provide reliable measures of the resource's value.

The second approach (surrogate market valuation) consists of measuring the value of unmarketable environmental services by looking at market price (or the shadow price) of related economic goods. These related goods may consist of: (i) environmental services' complementary goods (i.e. goods required to enjoy environmental services); (ii) substitute goods (i.e. goods which may replace environmental services, or reduce/avoid the economic impacts of changes in service flow); (iii) other marketable goods providing indirect information about the environmental change's economic impacts. Again, the surrogate market valuation approach is potentially capable of providing reliable welfare measures only if the value of the natural resource under consideration is revealed by related market behavior and market prices. This may occur for use values, but will never occur for non-use values. It follows that if a resource does not (only) provide benefits through its present (or expected) use, but because of its mere existence, the surrogate market valuation techniques are intrinsically unable to provide (reliable) value estimates.

Finally the third approach (expressed preference approach) consists of directly asking individuals which value they attach to unmarketable environmental services, and to express their preferences towards changes in service flows. This approach is potentially able to estimate both use and non-use values, or simply -when applied in a holistic way- a natural resource's total value.

On the one extreme of the "valuation spectrum" we may place *environmental attributes, underlying non-use values, holding pure public features:* these values can only be assessed through expressed preference methods. On the other extreme of this spectrum we may place *private/quasi-private marketed environmental attributes,* typically underlying direct-use values, which can be measured by directly exploiting market prices.

In-between points along this spectrum we find *quasi-public/public unmarketable environmental attributes, underlying direct or, more frequently. Indirect use values,* which can be assessed through surrogate market valuation or expressed valuation methods. The choice between these two valuation approaches mostly depends on (i) whether or not other relevant goods are involved in generating these values, and (ii) the economic nature of these related goods. When related goods hold private/quasi- private features (marketed or marketable goods), the surrogate valuation approach is potentially capable of inferring the value of unmarketable environmental attributes. On the contrary, when there are no relevant marketed goods involved, analysts must inevitably turn to expressed preference methods.

Direct and indirect techniques: The valuation literature provides various taxonomies of techniques developed to measure the economic value of unmarketable environmental attributes. Here we will adopt the taxonomy proposed by Pearce and Turner (1990) and Turner *et al.* (1994) who classify the available techniques as "direct" (or "environmental demand curve approach") and "indirect techniques" ("non-demand approaches").

The **direct techniques_**seek to directly measure the monetary value of environmental services. This may be done by looking for a surrogate market -typically the market of complementary goods or other factor inputs in the 'household's production function, in order to infer individuals' preferences, or by asking individuals to express their preferences. Following Pearce and Turner (1990) and Garrod and Willis (1999), the *travel-cost method,* the *hedonic price method,* and *the contingent valuation method* hold to the direct approach.

The **indirect techniques_**do not seek to directly measure individual preferences. "Instead, they calculate a "dose-response" relationship between [say] pollution and some effect, and only then is some measure of preference for that effect applied" (Pearce and Turner, 1990, p.142). According to Garrod and Willis (1999), because indirect techniques do not value the environmental commodity via a demand curve, they tend to fail to provide "true" valuation information and welfare measures. Although the literature does not provide an univocal and clear-cut classification of direct and indirect techniques, the so-called *production-function* and *cost-based valuation method* are usually included in the latter group.

7.5 The Production-function Method

The production-function method (otherwise known as "change-in-productivity approach", "effect on production approach", or "valuing the environment as an input") seeks to exploit the relationship between environmental attributes and the output level of an economic activity.

The underlying assumption is that, when an environmental attribute enters a firm's production function, environmental changes' economic impacts may be measured by looking at the effect on production, and by valuing such effect at market (or shadow adjusted) output prices. As underlined in the previous section, the money estimates obtained in this way should not be interpreted as the "true" value measure, but as a proxy of the environmental change's ultimate welfare impacts.

The Production-Function Approach (PFA) has been widely used, particularly to evaluate the impacts of environmental quality changes *(e.g.* acid rain or water pollution) upon agriculture *(e.g.* Adams et al. 1986) and fisheries *(e.g.* Kahn, 1991). Other examples of application include analysis of the impacts of water diversion (Barbier, 1998), and the valuation of the protection benefits provided by coastal wetlands against hurricane damage (Farber, 1987).

According to Barbier (1998), because of the direct dependence of many production systems in developing countries on natural resources and ecological functions, the PF A is considered widely applicable to many important economic and investment decisions in these countries,

Broadly speaking, the PF A consists of a two-step procedure. The first one is aimed at identifying the physical impacts of environmental changes on a production activity. The second step consists of valuing these changes in terms of the corresponding change in the activity's output.

Clearly, particularly at the first stage, co-operation is required between natural scientists, economists and other researchers, in order to determine the nature of the environment-production linkages (Barbier, 1998).

By indicating with Y the activity's output, with ENV the environmental variable(s) of interest, and with Xi (i=1, .N) other inputs, the production function of a representative firm might look like:

$$\mathbf{Y = f\,(Xi, ENV)} \qquad \mathbf{(1)}$$

If $\delta Y/\delta ENV$ is positive, then a change in ENV *(e.g.* an increase or decrease in water pollution) will, *ceteris paribus,* decrease/increase output levels.

Broadly speaking, when Y is a marketed good, and the observable price is not affected by relevant market-failures, this price (or a shadow adjusted price) can be used to estimate the value of a change in ENV. Alternatively, this value can be estimated by looking at the changes in marketed inputs (Xi) required to maintain a given level of output.

Various quantitative methods have been used to estimate the economic costs (or benefits) of environmental changes affecting production activities. Following Hanley and Spash (1993), these methods can be classified as follows: (i) "traditional' type models" (or "historical approach"); (ii) "optimization models"; (iii) "econometric models".

The **first method** is quite simple, and its main advantage is that the informational requirements are relatively modest. Once the physical relationship environmental variables and the output level has been identified, the monetary value of the environmental change is estimated by multiplying the output change by the current output price. The main caveat of this method is that it ignores possible price changes. Although prices may be unaffected by marginal environmental changes, significant and widespread changes in environmental conditions could entail not- negligible price effects, so that the assumption of constant price could provide seriously biased welfare measures.

The optimization models require extensive data sets, but provide more detailed information, and allow indirect effects to be considered. In particular, quadratic programming models allow to treat both price and quantities and endogenous variables. However, because of their normative nature, discrepancies may emerge between the model solutions and reality, and identifying the source of such discrepancies may prove difficult.

Finally, **econometric models** do not adopt a normative approach, but, by using observable data, and their variations over space or time (or both), try to get factual evidence about the inter-relationships of interest. "This applied work is objective in the sense that the results can be rigorously examined using accepted scientific and statistical methods, although ideological bias can be expected both in the selection of questions investigated and in the inferences drawn from factual evidence" (Hanley and Spash, 1993, p.1 06).

Leaving aside the above mentioned specific possible caveats arising from the choice of the quantitative method, a number of more general problems may arise when applying the PFA. Following Barbier (1998) these potential drawback may be summarized as follows.

Firstly, as already mentioned, the price of the output can be heavily distorted, i.e. it may fail to provide a reliable proxy of the output's economic value. Besides market failures, prices may be distorted by fiscal policies (taxation or subsidization). Moreover, public regulatory policies (or the absence of appropriate regulations) may influence the values imputed to the environmental input (ENV). For example, when considering the impacts of an environmental change, say a change in a coastal wetland supporting an off shore fishery, if the latter is subject to open-access conditions, "rents in the fishery would be dissipated, and price would be equated to average and not marginal costs. As a consequence, producer surplus is zero and only consumer surplus determines the value of increased wetland area" (Barbier, 1998, p.8).

Secondly, applications of the PFA may be most straightforward in the case of a natural resource ('s services) supporting only one economic activity (single use sources) than in the case of multiple-use resources. In fact, when a natural resource supports many different economic activities, "applications of the production function approach may be slightly problematic [...] and assumptions concerning the ecological relationships among these various multiple uses must be carefully constructed to avoid problems of double counting and trade-offs between the different values" (Barbier, 1998, p.8).

Finally, "for some valuation problems, choosing whether to incorporate inter-temporal aspects of environment can be very important" (Barbier,1998, p.9). For example, in their study aimed at estimating the value of estuarine wetlands and mangroves in supporting off-shore fishery in the state of Campeche (Mexico), Barbier and Strand (1998) have adopted, and compared, a "static valuation approach", and a "dynamic valuation approach". The former valuation exercise assumes that fish stocks are always constant. The latter attempts to model the impact of a change in coastal wetland area on the growth function of the inter-temporal fish harvesting process.

7.6 Cost-based Methods

When the impacts of environmental changes do not (exclusively) manifest themselves through changes in firms' marketed outputs, information on related costs can be used to obtain estimates of the welfare impacts.

Various techniques, falling within the broad class of "cost-based approaches", have been applied to estimate the social rate of return of projects which were expected to entail significant environmental changes, or to assess the impacts of actual changes in damage assessment cases.

Broadly speaking, these techniques can be classified according to: (i) the nature of environmental changes; (ii) the effects of such changes; (iii) the individuals' ability to react to them; and (iv) the nature of the reactive actions.

7.7 Averting Behavior and Relocation Cost Approach

Individuals may be able to react to environmental changes. For example, to avoid or reduce the health effects of increased water pollution, households may undertake averting expenditures such as buying bottled mineral water, spending energy (and time) to boil water, or acquiring water treatment equipment.

The averting behavior approach exploits individuals' willingness-to-pay for avoiding (preventing or mitigating) the effects of negative environmental changes in order to infer the value of environmental quality. If the costs incurred to mitigate, or prevent, the effects of pollution can be estimated with a reasonable level of accuracy, the value of decreasing (increasing) environmental quality may be inferred by looking at the increase (decrease) in averting expenditure (AE).

This valuation method relies on various assumptions which affect its ability to provide reliable estimates of the true' value of an environmental change. These assumptions may be summarized as follows: (i) AE and environmental quality are close "substitutes"; (ii) AE is only explained by the environmental change of interest and does not generate additional benefits; (iii) AE is reversible.

Similarly to the averting behavior approach, the relocation-cost method may fail to provide true valuation information and welfare measures, i.e. it may involve an underestimation or an overestimation of the economic value of pollution, depending on whether or not, by moving, individuals are able to recover the same level of environmental services, and on whether or not relocation is driven only by the environmental quality at different sites.

7.8 Cost of illness and Human Capital Approach

The cost-of-illness method has been quite frequently used to estimate the welfare effects associated to environmental changes involving changes in the level of morbidity. For example, this approach was adopted to estimate the economic benefits of pollution control measures undertaken in Santiago (Chile) to reduce the concentrations of air pollutants such as particulates, volatile organic compounds and nitrous oxides (World Bank, 1994).

The method can be applied when environmental changes have repercussions on human health, and when (it is assumed that) individuals are unable to react, i.e. when they may not undertake defensive actions (i.e. averting expenditures) to reduce health risks.

In these cases, the costs (benefits) of an increased (decreased) level of pollution can be estimated by using information on: (i) the relationship between environmental quality changes and changed in the level of morbidity; and (ii) the economic costs (benefits) associated with changes in the level of morbidity.

As far as the latter are concerned, besides medical costs, and other out-of-pocket expenses, any loss of earnings, due to an increase in morbidity, should be accounted for, in order to assess the welfare impacts of increased (decreased) levels of pollution involving health effects.

In principle, also non-market losses associated with sickness, such as pain and suffering to the affected individuals and other concerned, as well as restrictions to non-work activities, should be accounted for. However, these "intangible" effects are not in general taken into account, because of the difficulty to translate these effects into monetary values. This implies that the cost-of-illness estimates should, in general, be interpreted as lower-bound estimates of the "true" costs (benefits) associated to increased (reduced) pollution levels affecting health risks. Moreover, this method is intrinsically unable to evaluate the welfare effects of environmental changes which do not (exclusively) manifest themselves through changes in the level of morbidity.

The so-called human-capital approach is an extension of the cost-of-illness method, in that the environmental changes' impacts are assessed by looking at the relationship between environmental quality and mortality rates. However, this approach is much more problematic, in that it entails an estimation of the value of human life. This can be done by looking at the present value of an individual's future income stream. But, besides the difficulty in predicting the expected life-time earnings, reducing the value of life to individuals' expected productivity is extremely controversial, and some agencies have recommended not using this approach, and instead, to eventually use measures of the value of a statistical life based on willingness to pay estimates "which includes much more that just lost productivity and is often 5 to 10 or more times larger than the straight human-capital estimates" (World Bank, 1998),

7.9 Restoration Cost Approach

When restoring the environment to its original state i.e., restoring a natural asset's original service flow- is technically feasible, the restoration cost may be used as a measure of the costs (benefits) of (avoided) negative environmental changes.

The restoration cost approach has been quite frequently used in cost-benefit analyses of new projects and public policies, and, in some countries, forms the basis of compensable damage assessment *(e.g.* in the United States, under the Comprehensive Environmental Response, Compensation and Liability Act) (Garrod and Willis, 1999).

Besides requiring that the costs to restore a natural asset ('s services) can be estimated with a reasonable level of accuracy, this approach -which cannot be applied to very unique and irreplaceable assets- implicitly assumes that restoration costs do not exceed the economic value of the asset ('s services).

This assumption may not be valid in all cases. As argued by World Bank (1998), "it simply may cost more to restore an asset that it was worth in the first place" (p.6). More generally speaking, if environmental substitutes are available, and these substitutes can be acquired at a cost lower than the cost required to restore a damaged natural asset, then the restoration-cost method will provide an overestimation (an upper-bound estimate) of the "true" damage.

7.10 The Travel-Cost Method

The travel-cost method (TCM) was designed and is generally used to value environmental attributes which are exploited to acquire recreation services.

The intuition underlying the TCM is simple. Even when entry to a recreation site is free of charge, individuals willing to enjoy environmental attributes generally need to afford economic costs. Besides out-of-pocket expenditures (transport costs) individuals need to use other "inputs" (other economic goods), such as time, to gain access to a recreation site.

By looking at the total cost afforded to gain access to the recreation site, the TCM tries to infer the demand for the site. Once this demand -i.e. the relationship between the cost of visiting a recreation site and the number of visits observed- has been identified, the total benefit re-creators obtain can be calculated by using, as a welfare measure, the visitors' consumer surplus, i.e. the benefit visitors enjoy above the costs involved in carrying out the recreational activity.

The TCM can then be interpreted as a special case of the production function approach. More specifically, the TCM uses a "household-production framework"; in fact, as a firm may combine environmental goods with other purchased inputs to produce marketable commodities, households may get utility by combining environmental attributes with other economic goods, to acquire recreation services.

Traditionally, TCM studies have used one equation to model the number of trips people take to a specific recreation site ("single-site models"), and have assumed that the number of trips is a function of travel costs, and that the travel cost is proportional to distance from the site. Moreover, a single-purpose trip has been frequently assumed. All these assumptions are "often valid in the case of [tourism within a country but] may not be valid for international tourism" (World Bank, 1998, p.9).

Moreover, one of the major drawbacks of the single-site models is their inability "to account for substitution among recreation sites [and their] inability to determine the importance of individual site characteristics. If there are substitutes for the site, an increase in travel cost would induce people to visit another site rather than forego recreation altogether [...] Because the travel- cost model does not incorporate this substitution in any meaningful way, the method overstates the benefits of the recreation site (Desvousges *et al,* 1998, p.20).

"Multiple-site models" have been developed to overcome some of these drawbacks. However, even these models can only value a trip as a whole, and are unable to value changes of one specific environmental attribute of a site (Desvousges *et al,* 1998). This may pose problems when a valuation study is not aimed at assessing the value of a natural resource *per se,* but, say, at measuring the value of a negative environmental change. As noticed by McConnell (1993), for measuring environmental damages, "the successful use of the travel cost model requires not simply that the model itself reflects the demand for services of the public natural resource, but that the model accurately captures the change in demand for the service after the resource is injured" (McConnell, 1993, p.191).

TCM has been widely used to evaluate the use-value (recreational use value) of natural assets located both in developed and developing countries. As far as the latter are concerned, the main application is to valuing international tourists' willingness to pay for (visiting) wilderness areas. For example, Mekhaus and Lober (1996) have carried out a travel-cost study, aimed at assessing the benefits obtained by tourists visiting national parks and reserves in Costa Rica.

7.11 The Hedonic Pricing Method

Hedonic price valuation tries to measure the value of an un-marketed environmental service as a measurable component ("attribute" or "characteristic") of a marketed good (Anderson, 1993).

The method, which may be traced back to the characteristics theory of value developed by Lancaster (1966), relies on the proposition that an individual's utility for as a good is based on its attributes. As long as the latter include environmental attributes, by modeling individuals' willingness to pay for a particular good as a function of its characteristics, hedonic pricing tries to pick up the impacts of changes in environmental service flows upon individuals' utility.

The most common applications of the hedonic pricing method (HPM) try to exploit the relationship between property values -often, although not exclusively, residential property values- and environmental attributes of the neighborhood *(e.g.* air quality, noise levels, access to recreational facilities, visual amenities).

However, besides the so-called *property value approach* (World Bank, 1998), the HPM has been also applied to the labor market and wage rates: *the wage differential approach's* underlying assumption is that an individual's choice of a particular job may be affected by the job's location's surrounding environmental conditions or by the perceived risk of natural hazards *(wage-risk analysis)*

Basic steps

The typical steps of hedonic study may be broadly described as follows. The first one consists of selecting the environmental variable(s) of interest and of deciding the marketed good whose price is expected to provide information about the implicit environmental value(s) (henceforth, the "environmental price(s)").

As far as the dependent variable is concerned, either purchase or rental data may be used in property valuation studies, depending on data availability, data quality, and market conditions.

Assuming purchase price (e.g. house price) is used as the dependent variable, the second step consists of identifying all other explanatory variables which, together with the environmental variable (ENV), are thought to describe the property's attributes. The choice of the relevant attributes is potentially crucial (Hanley and Spash, 1993), in that failure to include property's relevant attributes correlated with some or all of the included characteristics, may lead to significantly biased estimates for these characteristics' implicit prices (i.e., *inter alias,* biased environmental prices).

Two particular "omitted-variable-bias problems" should deserve specific and special attention.

The first concerns the question of so-called "averting behavior" (Garrod and Willis, 1999), where owner-occupiers (landlords or tenants) spend money for preventing or mitigating neighborhood's negative environmental conditions. As noticed by Kuik *et al.* (1992), the effects of averting behavior (other than moving to a different location) are often neglected in hedonic studies because of the difficulties in acquiring detailed information.

The second problem has to do with the difference between actual and expected environmental changes. If an hedonic price study is aimed at inferring the value of an actual change in environmental conditions (say, the value a specific change in air quality), as long as property prices are also affected by expected changes (i.e. expected neighborhood changes are one of the property's attributes) excluding expected changes from property prices' explanatory variables leads to omitted variable bias (Hanley and Spash, 1993).

Expectations about future benefits (or costs) associated to environmental changes do not give rise to the afore-mentioned omitted variable bias problem, as long as these expectations concern future benefits -or costs- associated to actual (not expected) changes. In fact, as argued by Garrod and Willis (1999), each environmental attribute is not valued with respect to the benefits it currently provides, but for the stream *of* future benefits which it will subsequently generate. In other words, "house prices should reflect the capitalized value *of* environmental quality to the home-owner" (Hanley and Spash, 1993, p.75).

Once the analyst has identified a plausible set *of* relevant property's attributes (C_i; i=1... .N.), the next step consists *of* estimating an "hedonic price equation", holding the following general form:

$$\mathbf{P_H = f\,(ENV, C_i)} \qquad \mathbf{(2)}$$

The specification *of* function (2) plays a crucial role in hedonic studies. Since economic theory does not impose restrictions on the hedonic price function (Rosen, 1974), analysts may in principle adopt different functional forms, and "even for a given data set, criteria for functional form selection may be conflicting" (Hanley and Spash,1993 p.79).

Pioneering HPM studies have mostly adopted linear functional forms, which imply that the implicit prices *of* the property's attributes are constant. In other words, the marginal cost (or benefit) *of* ENV changes would be independent *of* the level *of* ENV and *of* the composition *of* property's attributes.

However, from Rosen (1974) onwards, many authors have argued that implicit prices are unlikely to be independent *of* the quantity *of* each property's attributes, since this would only occur *if* individuals were able to "re-package" property's attributes.

In other words, the hedonic price equation is expected to be non-linear. because "house buyers cannot treat individual housing attributes as discrete items for which they can pick and mix until their desired combination *of* characteristics is found. On the contrary, most properties embody a set *of* attributes which are not readily adjustable and home buyers are limited in their choice to those properties available on the market" (Garrod and Willis, 1999, p.112).

8.0 Total Economic Valuation

Economic valuation is still an evolving science. It is not that straightforward to identify and determine the value of environment. For some goods and services (for example one kilo rice or fish or a cubic meter timber) market provide prices that are good reflection of the values the society places on that goods and services. But there are no market prices of for any endangered species and cultural heritage and scenic beauty of nature. There is no easy and short cut method and process for measuring these benefits in money terms. There is wide rage of goods and services that include recreation tourism, conservation biodiversity (for food security and medicine), in situ preservation of gene pools, water supply, management of watershed, protection of natural disaster, carbon sequestration, grazing climate stabilization, agriculture, wildlife habitat, fuel wood, timer, ground water recharge, nutrient retention, spiritual values, cultural heritage, non-timber forest product and so on. Many of these goods and services are not traded on commercial basis. The market values many of these goods and services are non-existent. Still the value of the non market value of these goods and services needs to be measured and expressed in money terms, to the best possible way in order to make understand the importance of these resources to the policy makers and community people in order to protect and conserve these resources for their own and future generations. It is thus convenient to disaggregate any environmental impact into individual component of values, which called total economic valuation (TEV).

The concept of total economic valuation (TEV) in now well established and very useful framework towards identifying the various tangible and no tangible values of the resources and services of the environmental protection. The basic methodology to be followed for measuring and estimating the economic benefits of wetland described by Barbier. The taxonomy of economic values as they relate to natural environment is broadly categorized as user and non-user values, the main elements of which can be expressed as:

$$\begin{aligned} \mathbf{TEV} &= \mathbf{UV+NUV} \\ &= \mathbf{DUV+IUV+OV+NUV} \end{aligned}$$

Where TEV = total economic value
UV = use value
NUV = non-use value
DUV = direct use value
IUV = indirect use value
OV = option value

Following the above taxonomy the valuation of environmental loss/benefits can be described as follows;

Total economic value

Table 14 manifests different appropriate techniques regarding the measurement of the environmental benefits and costs such as recreation, fuel wood and wildlife habitat, flood control, and ecosystem services which have direct use value. The value of the production is obtained directly by exploiting these resources. Other different options of measuring the valuation of environment due to climate change are shown in the table 16.

Table 14: Total economic value of the environment due to climate change

Use values						Non-use values			
Direct values	**Valuation Approach**	**Indirect values**	**Valuation Approach**	**Option values**	**Valuation Approach**	**Bequest values**	**Valuation Approach**	**Existence value**	**Valuation Approach**
Recreation	TCM	Eco-system services	CVM	Future information	CVM	use and non-use values for legacy	CVM	Bio-diversity	Preventive expenditures / IS
Sustainable harvesting	Market Analysis	Climate stabilization	DCA	Future uses (indirect and direct)				Ritual and spiritual values	CVM
Fuel wood	MA	Flood control	DCA					Culture and heritage	
Wildlife harvesting	MA or IOC or IS	Ground water discharge	VCP					Community values	
Grazing	IOC	Carbon sequestration	DCA					Landscape	
Agriculture	MA	Habitat	IS						
Gene harvesting	Market Analysis /IS	Nutrient retention	IS						
Education		Natural disaster prevention	PE						
Research		Watershed protection Natural services	DCA						
		NTFP	MA/ replacement cost/IS						

Source: Adapted from Barbier et. el., (1997); Anderson and Billah, 2001

Note: MA = Market Analysis; DCA = Damage Cost Avoided; PE = Preventive Expenditures; RC = Replacement Cost; CVM = Contingent Valuation Method; TCM = Travel Cost Method; IOC = Indirect Opportunity Cost; IS = Indirect Substitute approach; VA = Valuation Approach

The limitations of the availability of data prevent comprehensive TEV of environmental benefits. TEV can provide approximate magnitude of benefits loss due to depletion of protected areas.

This framework has adopted a TEV approach in order to identify the array of values that are attributed to natural resource and environment because of this holistic perspective values. But there are certain things that should be kept in mind about the TEV:

(a) TEV is anthropocentric values in TEV, which are human –held values. This framework does not account for possible intrinsic values of biodiversity. There are other values unrelated to humans. Thus it is recognized that economics cannot fully account all the values attributed to natural resources and environment;

(b) The differences in perceptions of individuals result in variation of the values of resources. For example, one person may value the viewing elephant in it's the habitat, the other may value harvesting and hunting elephant for commercial purposes. In attempting to calculate total economic value for nature and environment , there is always chance of missing values, conflicting values and double counting;

(c) Full total economic valuation is not possible and feasible in many cases, an extensive exercise is costly, time consuming as well as cumbersome. Thus the valuation is rather purposeful and subjective according to the need of managers and decision makers.

(d) Values in local perception and international terms will make a big difference.

Whose value to be counted? What value to be estimated? and How to carry it out?

A structured assessment process would provide the direction of valuation and may save time and money at the end. The appropriate process would identify what the values will be used for, which values are important to measure, and which techniques of valuation are most appropriate. The assessment process follows three steps;

(a) Definition of the audience.

(b) Determine the scope of the study.

(c) Chose the appropriate analytical techniques.

The breakdown and terminology for the components of TEV vary slightly from analyst to analyst, but generally include (i) direct use value (ii) indirect use value (iii) non-use value.

Table 15: Use and Non-use values

Use values	Definition	Examples
Direct use value	Direct use value, has been categorized into extractive and consumptive, derives from goods which can be extracted, consumed, or directly enjoyed.	Extractive use value of forest would be derived from timber, harvest of minor forest and products; consumptive such as fruit, herbs, or mushrooms, and from hunting and fishing. Extractive use value for agricultural products. Similar valuation needed for loss of resources due to climate change and for the case of Sidr for Sunderban.

Use values	Definition	Examples
Indirect use value	Indirect use value, also known as non-extractive use value or functional value that derives from the services the environment provides.	Wetlands often filter water, improving water quality for downstream users, (in other words, wetland is called "biological supper market" and "kidney of landscape") and national parks provide opportunities for recreation. Similarly, grazing land for livestock, wildlife and fishery sanctuary. The visual aesthetic benefits provided by a landscape, for example, are non-rival in consumption, meaning that they can be enjoyed by many people without detracting from the enjoyment of others. Similar valuation needs to be conducted due loss of resources and amenities due to climate change, where inventory of resources and potential services to be made available.
Option Value	Option value is the value that obtained from maintaining the option of taking advantage of something's use value (whether extractive or non-extractive) at a later date.	Akin to an insurance policy. This is more pertinent to the vulnerability of climate change.
Non-use values	**Definition**	**Examples**
Existence value	The value that people derive from the knowledge that something exists, even if they never plan to use it.	People place a value on the existence of blue whales, or of the panda, even if they have never seen one and probably never will; if blue whales became extinct, many people would feel a definite sense of loss. Similar is germplasm and genepool.
Bequest value	Bequest value is the value derived from the desire to pass on values to future generations.	Reflected in people's behavior and is thus wholly unobservable. Non-use value is the most difficult type of value to estimate, since in most cases it is not, by definition is unobservable.

Valuation techniques

For incorporating environmental impacts in the EIA towards project analysis has a two-step process. First, one is the understanding of what are the environmental impacts for undertaking a development project and future risk factor that economy might encounter due to climate change and natural disaster. This information is provided by a traditional economic analysis. Second, one is the estimating the value of the environmental impacts (where feasible and appropriate) converting quality changes of resources and environmental degradation of services into money terms to determine their relative economic importance, and assess the benefits and costs of various alternatives. Total Economic Valuation (TEV) as shown in the flow chart describes a number of valuation techniques which are potentially applicable to each category of value.

The biggest difficulty in valuing such impacts generally arise from measuring the amounts of goods being produced and in predicting how these amounts will change with and without the project. Environmental valuation in EIA can be very helpful in arriving at estimates of these changes. Once these estimates are in hand, valuing the changes is usually relatively simple.

For convenience of economic analysis that integrates the values of environmental loss and benefits into planning process, the valuation techniques of environmental impacts may be classified into two groups:

i. Cost approach
ii. Benefit approach

Cost-based approaches

When the benefits of a given environmental impact cannot be estimated directly, indirectly, information on costs can be used for valuation. For example, in order to estimate the magnitude of environmental impacts the potential costs (or savings) to society from a change in an environmental problem, can be obtained by using the cost of reducing or avoiding the impact, or the cost of replacing the services provided by the environmental resource. The major underlying assumptions of these approaches are;

(i) the nature and extent of physical damage expected is predictable (there is an accurate damage function available), and

(ii) the costs to replace or restore damaged assets can be estimated with a reasonable degree of accuracy. It is further assumed that these costs can be used as a valid proxy for the cost of environmental damage. That is, the replacement or restoration costs are assumed not to exceed the economic value of the asset.

These are strong assumptions that may not be valid in all cases. It may cost more to replace or restore an asset than it was worth in the first place. For example, cultivated hillsides may cause to erode soil and there may be different methods available for estimation of cost (terracing, changes in cropping patterns) to reduce or prevent the erosion.

In estimating each of these preventive measures, there is cost involvement, however, it is the responsibility of the analyst to determine level of costing and the total costs of prevention are greater or less than the benefits of preventing erosion. In some cases, the costs of erosion control may be so high (and/or the benefits from controlling erosion may be so low) that erosion control measures would be an inappropriate use of scarce resources. In some cases, there may also be more cost-effective ways to compensate for environmental damage than to replace the original asset or restore it to its original condition, and these substitution possibilities are ignored with the use of this technique.

Table 16: Cost-based approaches

Types of Cost based approaches	Definition	Examples
Replacement cost	This approach is often used as an estimate of the cost of pollution. This approach focuses on potential damage costs as measured by *ex ante* engineering or accounting estimates of the costs of replacement or restoration if damage from pollution were to occur.	For example, the costs of air pollution-related in urban areas could be approximated by the restoration and replacement costs from damaged infrastructure. Similarly, the cost of restoring a river or a wetland or infrastructure could be used as an estimate of the costs of environmental damage to these natural assets due to climate change. Pollution of water resources by agrochemicals is common in many countries, resulting in drinking water below acceptable health standards.
Relocation cost	The relocation cost approach uses to estimate the costs of a forced relocation of a natural or physical asset due to environmental damage.	The construction of brackish water ponds in a coastal area resulted in the discharge of salt water into nearby freshwater streams traditionally used for irrigation and domestic water supply. This may happen due to climate change.
Opportunity cost	The term opportunity cost refers to the value of these losses of economic opportunities due to environmental protection.	A measure of the cost of environmental protection in terms of development benefits foregone.

Benefit Approach: amenities and recreation,

Some of the environmental good or service being valued is not traded per se in the market place. Examples of these amenity-type services include recreational sites and the preservation of biodiversity. Available valuation techniques that exist cannot be used to place monetary values on these resources and this information, in turn, can be incorporated into a more conventional benefit-cost analysis. In order to overcome these difficulties the following valuation method can be adopted.

Table 17: Benefit approach

Types of Cost-based approaches	Definition	Examples
Hedonic Price Method	Hedonic models have been widely used to examine the contribution of different attributes to prices for housing and to wage levels, including the contribution of environmental quality.	Lake front hotels and housing for example, charge different rates depending on the view (rooms with lake views cost more than the same size room with a "garden" view —usually a nice way of saying the parking lot!). The

Types of Cost-based approaches	Definition	Examples
		reverse is the case for house rent in polluted area like Matuail and Badda in Dhaka city. Similarly, opportunity cost for losing sea beach due to climate change and natural disaster.
Travel cost	The travel cost (TCM) method is an example of a technique that attempts to deduce value from observed behavior. It uses information on visitors' total expenditure to visit a site to derive their demand curve for the site's services. The technique assumes that changes in total travel costs are equivalent to changes in admission fees. From this demand curve, the total benefit visitors obtain can be calculated. The technique also assumes a single-purpose trip and encounters difficulties when trips have multiple purposes. It should also be borne in mind that the resulting estimates are site-specific. The main application of TC methods in developing countries is to valuing tourists' willingness to pay for national parks.	TCM is the analysis of tourists found that they derived about in US$ per person of benefit (consumer's surplus) obtained from visiting national parks. Opportunity cost for losing national park and amenities due to climate change and global warming.
Contingent valuation	The Contingent Valuation (CV) technique relies on direct questioning of consumers (actual or potential) to determine their willingness-to-pay (WTP) to obtain an environmental good.	A detailed description of the good involved is provided, along with details about how it will be provided. The actual valuation can be obtained in a number of ways, such as asking respondents to name a figure, having them chosen from a number of options, or asking them whether they would pay a specific amount (in which case, follow-up questions with higher or lower amounts are often used).

Integrating environmental costs and benefits into economic analysis

The choice of technique depends on the specific problem being studied. Except in very simple situations, however, it is likely that a variety of techniques will be necessary to estimate the full range of benefits. Moreover, where substantial investments are contemplated, it might be desirable to cross-check estimates by deriving them from multiple sources. Once the various environmental impacts have been identified and the benefits and costs of various alternatives assessed, this information can be incorporated into the broader economic analysis of the project. This is usually done in a benefit-cost framework, whereby the streams of benefits and costs of a proposed project (including direct project inputs and outputs, as well as environmental impacts to the extent that they can be identified and monetized) are compared over some period of time.

The three main decision criteria used in benefit-cost analysis are: *net present value* (NPV), *internal rate of return* (IRR) and *benefit-cost ratio* (BCR). All of these criteria rely on the concept of discounting a stream of benefits and costs which occur at different times over the duration of the project being evaluated. Discounting puts all of these costs and benefits into a common time frame to allow for more accurate comparison. Adding environmental costs and benefits does not change the method of analysis and guidance is available in various publications, such as the Handbook on Economic Analysis of Investment Operations by the World Bank.

However, several aspects of project analysis need particular attention when environmental problems are present. The impacts of many environmental changes, whether positive or negative, are often only felt in the future, long after the activity which caused the change has ceased. Similarly, effects are often felt far beyond the boundaries of the project itself. Special attention must be given, therefore, to the *temporal* and *spatial boundaries* of the analysis.

Temporal Boundaries

Since environmental impacts extend long beyond the normal life of the project, it is important to extend the time horizon of the analysis so as to include all the benefits and costs associated with environmental impacts, even if they go further into the future than the normal life of a project. The effective length of the time horizon of an analysis is determined by both the number of actual years included in the analysis and the discount rate used. Using too short a time horizon effectively ignores many environmental impacts, both positive and negative. For example, an activity that results in the permanent loss of a fishery should include in the analysis the present value of the entire future loss of that resource, even if the activity itself only lasts for a few years. The choice of the appropriate *discount rate* is also an important decision, since a high discount rate effectively reduces to zero the present value of benefits and costs that occur many years in the future. Given the importance of the discount rate, however, it is important to do sensitivity analysis using different discount rates. This can yield useful information to the decision maker when comparing alternatives that have very different time profiles of benefits and costs (including environmental ones).

Spatial Boundaries

When environmental effects are present, careful thought must also be given to the appropriate *spatial boundary* of the analysis. The analyst often has to look far beyond the geographical boundaries of the project itself, especially when water or air pollution is involved. In other cases, global aspects may be important and require a further expansion of the "accounting stance" of the analysis. With both spatial and temporal externalities, the important rule is to be transparent in the assumptions being made, and explicitly state the adjustments that have been used in defining the analytical boundaries for the project—both in space and over time. Whatever the actual techniques used to estimate the value of environmental benefits or damages, an important point that should be borne in mind is the likelihood of

underestimation. Inevitably, some types of value will prove impossible to estimate using any of the available techniques, either because of lack of data or because of the difficulty of extracting the desired information from them. To this extent, any estimates of value will underestimate the total value; the estimates of project benefits will, therefore, be conservative, while estimates of costs will be optimistic. That some environmental benefits cannot be quantified, however, does not mean that they should be ignored.

Another potential problem which must always be considered is the risk of **double-counting**. The likelihood that total benefits will be underestimated because some benefits cannot be measured is well-recognized. Less well recognized is the opposite danger: that benefits (even if accurately measured) might be overestimated because some benefits are counted twice.

An example will illustrate the problem. Suppose that the project aims to reduce air pollution at the site by relocating or shutting down polluting activities. The benefit of this reduction could be estimated by predicting the reduction in the prevalence of respiratory illnesses and valued using the reduction in treatment costs. At the same time, suppose that a hedonic technique is used to estimate the value of overall environmental quality. Since air pollution is part of environmental quality, treating these two estimates as though they described separate problems and adding the corresponding benefits together would be inaccurate.

9.0 Result Discussion

As discussed earlier, the country has about 8.5 mha of cultivable land of which 7.85 mha is under agriculture where the net cultivable area 37% is single cropped, 50% double cropped and 13% triple cropped. Aman is the leading rice crop followed by boro and Aus. Due to double or triple cropping, the total cropped area amounted to about 17 mha. Since 1986-87, the cropping intensity is gradually increasing from 150% to 176%. In 2005-06 annual production of rice was 26.53 million tons where 0.73 million tons of wheat was produced (BBS, 2007) and thus Bangladesh tends to the level of self-sufficiency. Rice and wheat production data for 1999-2000 to 2005-06 obtained from agricultural statistics and BBS and presented below in Table 18. Total value of rice and wheat was estimated by the study team, using current wholesale rice and what price. Table 18 clearly demonstrated the increasing trends of rice production against the decreasing trend of wheat production in the recent years. Under the prevailing condition of the increasing demand for wheat the cost of import seems to be very high, especially with skyrocketing wheat price in the global market.

Table 18: Yield Production from 1999-2000 to 2005-2006

Year	Rice Production Ton	Yield/acre kg	Value mln Tk	Wheat Production Ton	Yield/acre kg	Value mln Tk
2005-06	26,530,000	1,020	593,741	735,000	620	14,994
2004-05	25,157,000	982	516,389	976,000	707	18,544
2003-04	26,190,000	997	436,674	1,253,000	790	23,807
2002-03	25,188,000	946	423,074	1,507,000	863	28,633
2001-02	24,299,000	922	408,142	1,606,000	876	30,514
2000-01	25,086,000	940	421,361	1,673,000	876	30,114
1999-2000	23,067,000	918	346,005	1,840,000	760	29,440

Source: BBS 2000-01-2006-07
Note: Estimate by the study team

Impact of climate change on crop Agriculture

It is obvious that impact of climate change on various sectors especially on agriculture will seriously affect the total agriculture production in general and the crop agriculture in particular. With the rise in CO_2 level positive fertilization effect will occur but with the rise in temperature the yield will be suppressed. The interaction of CO_2 and temperature thus has to be synchronized with the choice of crop cultivars in order to derive the desired benefit. The vulnerability of climate change and its impact on agriculture is attempted to clarify in terms of the yield sensitivity through crop model studies and also in terms of degradation of agro environment due to climate change. Value of aggregated rice and wheat production changes under different climate change scenarios is presented in Table 19. 1999-2000 was selected as base year due to availability of rice data sector wise. From this table, it is clear that aggregated rice and wheat yield have positive fertilization effects with CO_2 rise, however it will not sustain and lowered with the rise in temperature.

Table 19: Value of Aggregated Rice and Wheat Production Changes under Different Climate Change Scenarios

Simulation	HYV Aus			HYV Aman			HYV Boro			Wheat		
	Tonnes	Value * Mln Tk	Percent Change	Tonnes	Value * Mln Tk	Percent Change	Tonnes	Value * Mln Tk	Percent Change	Tonnes	Value * Mln Tk	Percent Change
Baseline (1999-2000)	798,000	13,709	-	3,246,000	78,650	-	10,671,000	204,883	-	1,840,000	26,680	-
CCCM	582,540	10,008	(27)	3,019,000	73,150	(7)	10,351,000	198,739	(3)	1,472,000	21,344	(20)
GFDL	582,540	10,008	(27)	2,824,000	68,425	(13)	9,924,000	190,540	(7)	717,600	10,405	(61)
330 ppmv CO_2 +2°C	646,380	11,104	(19)	2,824,000	68,425	(13)	10,244,000	196,684	(4)	1,159,200	16,808	(37)
330 ppmv CO_2 +4°C	494,760	8,499	(38)	2,435,000	59,000	(25)	9,924,000	190,540	(7)	588,800	8,537	(68)
580 ppmv CO_2 +0°C	**1,045,380**	**17,959**	**31**	**4,058,000**	**98,325**	**25**	**13,125,000**	**252,000**	**23**	**2,539,200**	**36,818**	**38**
580 ppmv CO_2 +2°C	901,740	15,491	13	3,603,000	87,300	11	12,805,000	245,856	20	1,821,600	26,413	(1)
580 ppmv CO_2 +4°C	750,120	12,887	(6)	3,278,000	79,425	1	12,378,000	237,657	16	1,104,000	16,008	(40)
660 ppmv CO_2 +0°C	1,117,200	19,193	40	4,317,000	104,600	33	13,872,000	266,342	30	2,723,200	39,486	48
660 ppmv CO_2 +2°C	973,560	16,725	22	3,863,000	93,600	19	13,552,000	260,198	27	2,005,600	29,081	9
660 ppmv CO_2 +4°C	829,920	14,258	4	3,538,000	3,325	9	13,125,000	252,000	23	1,269,600	18,409	(31)

Source: First National Communication for UNFCCC, 2002

*Note: Estimate by the study team; Percentage figure within parenthesis is negative. *Rice price calculated taking the average price of coarse, medium and fine rice for the year of 2005-06.*

From the analysis of previous chapters, it clearly demonstrated that impact of climate change on various sectors especially on agriculture will seriously affect the total agriculture production in general, and the crop agriculture in particular. Understanding of the country's climate as well as the regional climate for its obvious relationship needs to be made clear.

An analysis of rice production under different climate scenario is presented in table 19, where the average aggregated production of HYV Aus rice in Bangladesh was 798 thousands tons during 1999-2000 (BBS 2001). The worth of value Tk 13.709 million for HYV Aus, Tk 78,650 million for amon, Tk 204,883 million for Boro and Tk 26,680 million for wheat. This is for the base line year 1999-2000.

The production is reduced by 27% under CCCM and GFDL3 scenarios. The worth of which has also changed in money value worth of Tk 10,008 million

The production will increase by 31% and 40% respectively when the CO_2 levels increases to 580 and 660 ppmv without any temperature rise. The worth of which has also stood in money value worth of Tk 17,959 million and Tk 19,193 million respectively.

Rise of temperature by 2^oC at 330 ppmv CO_2 results in 19% reduction in aggregated production level. While, 2^0C temperature rise at 580 and 660 ppmv CO_2 increases the aggregated production by 13% and 22%. The worth of which also increases in money value worth of Tk 15,491 million and Tk 16,725 million respectively.

Further increase in temperature to 4^oC at 330 and 580 ppmv CO_2 levels reduces the production by 38% and 6%; respectively, but increases the production by only 4% at 660 ppmv CO_2 level (USCSP 1996). The worth of which also decreases in money value worth of Tk 8.499 million and Tk 12,887 million respectively. For HYV Aman Rice, HYV Boro rice and wheat production under different climate change cenarios are given in the Table-19.

Inundation and Sea Level Rise (SLR)

Temperature, rainfall, solar radiation, prolonged drought and less cool winter period are the prime factors to influence agriculture due to climate change. Higher temperature and water stress would result in declining vegetation and thus agricultural production. As per IPCC, in summer temperature will rise which will induce higher evapo-transpiration, resulting in more water demand by the plants. Cropland will suffer from water stress resulting in loss in crop yield as well as crop and forestry spices. With the rise in winter temperature (as per IPCC) and due to reduction in the cool water periods, many of the areas now suitable for production of different crops like wheat will turn unsuitable or the yield will reduce greatly.

Climate change will result in increasing summer rainfall by 11% and decreasing winter rainfall by 3% by the year 2030 (World Bank, 2000). As predicted, by the year 2050, sea level rise will be 50 cm. when summer rainfall will increase by 28% and winter rainfall will fall 37% by the year 2050. In summer, increasing rainfall will result in greater surface water flow and thus flooding. Due to flooding, agricultural production loss will be more pronounced. During winter, water demand will be more, and the present tendency of irrigation expansion will continue. Due to sea level rise, as predicted by IPCC 4th Assessment report 2007, 7-16% of the land area of the coastal area of Bangladesh will go under water, resulting in loss of land. Much of the grazing lands now available or remains seasonally fallow in the coastal belt will be lost, depriving the livestock population from the natural feed. Due to sea level rise under different climate change scenarios in different models it is observed that if sea level rises to 100 cm, 1.7% area of total country (2,500 KM^2) will be inundated. Inundation area due to Sea Level Rise (SLR) has been collected from Global Circulation Model which was done during the preparation of National Communication for UNFCCC and presented in Table 20.

Climate change and sea level rise will cause more cyclones and storm surges resulting in higher salinity in the coastal zone. Bangladesh serves as the natural drainage for nearly 1.66 million-km^2 catchments area, of which nearly 92.5% is out of the country's territory. Because of the sea level rise, backwater thrust will create hindrance in the drainage of surface water flow.

Table 20: Inundation due to Seal Level Rise

Seal Level Rise (m)	Inundation (km^2)	% of total Country Inundation
0.1	2,500	1.7
0.3	8,000	5.4
1	14,000	9.5
1.5	22,320	15.2

Source: Initial National Communication for UNFCCC, 2002

The rice crop is most affected by flood. The growth of the plant is hindered by the flood due to excessive moisture at the root zones, resulting in an overall decline in production of the crop. Transplanted Aman paddy does not grow well under submerged conditions of over 90 cm water depth. In Bangladesh about 1.0 Mha of cropland is highly and nearly 5.0 Mha is moderately flood prone. Usually, the flooding depth varies from 30 to 250 cm. The flash floods often damage the boro rice. The increase of rainfall with the change in climate in the future would produce even more severe floods of different nature causing greeter severe damage to rice crop and others.

Agricultural drought refers to a condition when the moisture availability at the root zone is less than adequate. This is how; Aman cultivation suffers from periodic drought conditions during Khanif II season. Similar conditions are often observed in early pre-Kharif period; affecting Boro and in Rabi season, wheat cultivation in the northeast and central-east regions of the country. Dry season drought affects the production of wheat, potato, mustard and Aus Paddy. Drought normally affects about 2.3 Mha of cropland during April to September and 1.2 Mha in the dry season. Drought during Kharif severely affects the transplanted Aman rice incurring annual production loss by about 1.5 Million Ton of rice.

The vast coastal croplands suffer from salinity related problems in the winter months. This is particularly common in nearly 1.0 mha of the present salt affected soil in the coast. Because of cyclone and storm surges, high spring tide inundation and capillary actions salt accumulate at the surface and root zones. As a result, a large area in the coastal districts is virtually unsuitable for a number of crops, while the production of other crops is less due to salt injury. About 0.13 Million Ton food grain is lost annually due to adverse impact of soil salinity. Thus, due to extension of saline area and salt effect, crop loss will be higher. Grain production and animal population production loss were calculated under the GCM model and estimated by study team which are presented in Table 21 and Table 22.

Table 21: Grain production loss due to SLR

Grain type	Total Production in 2005-06	Value Mln Tk	Production loss due to SLR in Mln TK			
			Loss against 0.1m SLR	Loss against 0.3m SLR	Loss against 1m SLR	Loss against 1.5m SLR
Rice	26,530,000	593,741.4	10,094	32,062	56,405	90,249
Wheat	735,000	14994	255	8097	1424	2279
Maize	400,000	16	0.27	0.84	1.48	2.37
Pulse*	316,000	18.96	0.32	1.02	1.80	2.88

Note: Estimated by study team. Wholesale price for rice Tk 22.38/kg, wheat Tk 20.40/kg, maize Tk 39/kg and pulse Tk 60/kg quoted from BBS 2007.

Table 21 clearly identified higher the sea level rise, the wider the area of inundation, the greater the risk for food insecurity. This results in life and livelihood of the people and development of the nation at stake.

Table 22: Animal population production loss due to SLR

Animal group	Animal population for 2005-06	Total value Mln Tk	Production loss due to SLR in mln TK			
			Loss against 0.1m SLR	Loss against 0.3m SLR	Loss against 1m SLR	Loss against 1.5m SLR
Bovine	25,135,000	301,620	5,128	1,6287	28,654	45,846
Goats	17,459,000	34,918	594	18,856	3,317	5,308
Poultry	188,398,000	13,188	224	712	1,253	2,005

Note: Estimated by study team. Price for bovine Tk 12,000, for goats Tk 2000 and poultry Tk 70 quoted from SIDR Study 2008.

Against similar inundation scenario, livestock, and poultry production of the country will also be at stake, which is the cheapest available sources of protein for the people at large. The value of the loss indicated the high cost for import that hardly nation can afford it.

10.0 Conclusion and Recommendations

The global climate change and frequent change in the variability of the climatic condition of the country have direct impacts on agriculture and the environment in various ways. For example, erratic precipitation coupled with climate change regime has adverse effects on the wetland resources, ecosystems, biodiversity and eventually the livelihood of the people. Salinity intrusion due to sea level rise has serious impact on the estuarine area and all forms of life on it. The empirical evidences indicated that this would continue to aggravate further following the upcoming more stress from the changed climate regime, unless it is addressed in time.

This is obvious that low lying poor countries like Bangladesh are the most vulnerable to climate change. This requires that climate change issues be fully integrated into development policy framework, and the project design should be appropriately made. The rich countries should honor their pledges to increase support through overseas development assistance and research into new crop varieties. This will help make the vulnerable country more resilient to natural disaster and calamities.

Against this backdrop, there is urgent need for determining the economic costs of the impacts of climate change for Bangladesh. This requires to make an assessment of the physical impacts of climate change on human life and on the over all development and environmental impacts of the country. This needs economic modeling and comparisons of current level social costs with future trajectories. This is also very essential for future economic planning and design, promoting technologies, propagating biotechnologies and future investment planning of the country as well.

The review of climate change issues provides for Bangladesh prepare a road map along the findings to apply and create some leverage and argument in the climate change negotiation to demand and seek necessary and adequate investment funding to ensure climate resilient development for the future.

The economic analysis and estimated costing for Bangladesh's vulnerability and susceptibility to climate change, disaggregated across sectors, could indicate investment requirements to assure climate resilient development. The adaptation deficit for Bangladesh can be determined to a large extent from such analysis. This could contribute greatly to rationalize and secure funds from development partners.

This calls for development efforts to integrate climate risk management such that development becomes resilient to climate changes. Thus mainstreaming climate risk management and adaptation into development planning and processes is the first foundation that each country must establish which is critical and paramount. The study of estimating cost for climate change provides the basis to ensure systematic assessment of risks, exploring options for risk management, and calculating the investment needs for climate resilient development and the value of the damage avoided.

Further, sharing of our mutual concerns and options can play a vital role toward consensus building, leading to common positions in key areas, for collective bargaining in international processes and institutions such as the UN Commission for Sustainable Development

(UNCSD), United Nations Framework Convention on Climate Change (UNFCCC), Kyoto protocol, International Financial Institutions and development partners.

The analysis of earlier studies reveals that despite facing several constraints on development-low natural resource base, inadequate human skill, poor technologies, high population density, severe vulnerability to floods and cyclones-Bangladesh has made steady economic progress in recent decades. The national poverty rate declined by an average of 2 per cent annually between 2000 and 2005, stable GDP growth achieved that averaged over 6 per cent annually during FY2003-07. A snapshot of the economy in FY07 shows that the services sector accounted for 49 per cent of GDP, the agricultural sector for 20 per cent and manufacturing and mining for 18 per cent. This progress clearly demonstrates the strong resilience of the economy. But still the country remains poor with per capita GDP of US$488 and poverty rate of 40 per cent (2005).

The impact of the recent cyclone Sidr and frequent flood is by far the most severe in the agricultural sector, at more than Tk 23 billion (US$ 333 million), which accounts for 89 per cent of the total loss in value added (GOB-WB, 2008). With the output losses in agriculture, the share of the agriculture and fishing sector in GDP is expected to fall; this will result in falling employment and rising poverty in turn. It is predicted that all economic losses will be incurred in FY08 and in subsequent years seems reasonable, given that nearly 90 per cent of losses in value added are in agriculture, and consultations with the sectoral ministry have suggested that agricultural production should fully recover in FY09, if other things remain the same.

In Bangladesh context the immediate climate change impact is on households lives and livelihood. This requires early recovery and finally the long term strategy for sustainable development against adversity of nature. Households are using various coping mechanisms in reaction to cyclone damage. The victim households are adopting coping strategies that include borrowing from relatives and neighbors; relying on relief from government, NGOs, philanthropic organizations and people and finally changing the normal diet; reducing the frequency and quality of meals; searching for "wild foods" from the forest, instead of normal market purchase; using savings to meet basic needs.

The assessment of Sidr found that about two-thirds of households own agricultural land and slightly more than half of the employed population has an agricultural sector occupation, but only one-third of households have their own agricultural sector production as their main source of income. A quarter of all households get most of their income from wage labor (of which a majority is in the agricultural sector, including fisheries and forestry), 30 per cent live mainly off small nonfarm businesses and many depend chiefly on rent; remittances, and other sources of income.

In order to undertake the early recovery program to meet the immediate needs that will provide the first opportunity for the affected population to rebuild the homes, lives, and living environment devastated by Sidr and other climate change events. This also needs an immediate food security survey and assessment for food, cash income, and clothing requirements.

The other immediate urgent attention needed is to improve the health of the population by providing shelters, medication, and clean drinking water. The early recovery strategy consists of three main lines of intervention (food security, shelter and health care), each having high relevance at a particular time after the disaster of climate change events. Thus early recovery stages would include interventions designed to ensure food security (saving from starvation) health care during post disaster events, livelihood and shelter for the disaster-affected people. The most immediate medium term to long term strategy would require concentrating on recovery of sustainable production in agriculture without further delay, the other opportunities like industry, commerce, reconstruction of infrastructure to improve risk assistance. This aims to reduce risk exposure and enhance coping abilities of the nation.

Effective disaster risk management is essential requirement for the future, especially in the post disaster with climate change being a likely factor. This requires risk identification, and appropriate assessment of predicted loss and damages, assessment of existing capacity of emergency preparedness, strengthening and leveraging of these. An assessment of existing institutional and community capacity also needs to be made. This requires necessary efforts to be made for further capacity enhancement. The assessment of investment requirement for mitigation and adaptation as outlined by national action plan for adaptation (NAPA) needs to implemented and potential investment sources to be explored.

In future studies, further efforts need to be made for impact assessment due to climate change events and assessment for investment requirement plan beyond agriculture to other sectors. These include industry, manufacture and service sectors.

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