सत्यमेव जयते

जहाँ है हरियाली ।
वहाँ है खुशहाली ।।

giz Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

COOPERATION
REPUBLIC OF INDIA
FEDERAL REPUBLIC OF GERMANY

The Economics of Ecosystems and Biodiversity - India

Initial Assessment and Scoping Report
Working Document

Ministry of Environment and Forests
Government of India

2012

The Economics of Ecosystems and Biodiversity - India
Initial Assessment and Scoping Report
Working Document

Supported by

Ministry of Environment and Forests
Government of India
Paryavaran Bhawan, CGO Complex
New Delhi 110 003 India

Indo-German Biodiversity Programme
GIZ India
B-4, Greater Kailash Enclave, Part II
New Delhi 110 048 India

Authors

Kirit S Parikh, Chairman IRADe, New Delhi
NH Ravindranath, IISc, Bangalore
Indu K Murthy, IISc, Bangalore
Swapan Mehra, Iora Ecological Solutions, New Delhi
Ritesh Kumar, Wetlands International South Asia, New Delhi
EJ James, Karunya University, Coimbatore
E Vivekanandan, Madras Research Centre of Central Marine Fisheries Research Institute, Chennai
P Mukhopadhyay, Department of Economics, Goa University, Goa

Photo Credits

Deepak Apte, Farhad Vania, JR Bhatt, Pradeep Vyas, Ravindra Singh, Ritesh Kumar, V. Selvam

Suggested Citation

Parikh KS, Ravindranath NH, Murthy IK, Mehra S, Kumar R, James EJ, Vivekanandan E, Mukhopadhyay P (2012) The Economics of Ecosystems and Biodiversity - India: Initial Assessment and Scoping Report. Working Document 157pp.

Contents

List of Tables, Figures and Annexures

Tables

Figures

Maps

Annexures

List of Abbreviations

AWC	Asian Waterbird Census
AWiFS	Advanced Wide Field Sensor
BNHS	Bombay Natural History Society
BSI	Botanical Survey of India
BTM	Benefit Transfer Method
CAMPA	Compensatory Afforestation Fund Management and Planning Authority
CBD	Convention on Biological Diversity
CDM	Clean Development Mechanism
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMFRI	Central Marine and Fisheries Research Institute
CMS	Convention on Migratory Species
CO_2	Carbon dioxide
CPCB	Central Pollution Control Board
CRZ	Coastal Regulation Zone
CSO	Central Statistical Organisation
CVM	Contingent Valuation Method
DFID	Department for International Development
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EM	Ecological Modelling
FAO	Food and Agriculture Organization
FSC	Forest Stewardship Council
FSI	Forest Survey of India
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GIS	Geographic Information System
GIST	Green Indian States Trust
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GNP	Gross National Product
GOI	Government of India
GSDP	Gross State Domestic Product
ICAR	Indian Council for Agricultural Research
ICDP	Integrated Conservation and Development Project
IEG	Institute of Economic Growth
IGIDR	Indira Gandhi Institute of Development Research
ISRF	India State of Forest Report
ISRO	Indian Space Research Organization
IUCN	International Union for Conservation of Nature
kms	Kilometers
LCA	Life Cycle Assessment
LISS	Linear Imaging Self-Scanning Sensor
MA	Millennium Assessment
MEA	Millennium Ecosystem Assessment

Mha	Million hectare
MNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MoEF	Ministry of Environment and Forests
MoRD	Ministry of Rural Development
MPA	Marine Protected Area
MSE	Madras School of Economics
MSS	Multispectral Scanner
Mt	Metric ton
MV	Market Value
NAPCC	National Action Plan on Climate Change
NBAP	National Biodiversity Action Plan
NBFGR	National Bureau of Fish Genetic Research
NCEPC	National Committee for Environmental Planning and Coordination
NGO	Non Governmental Organization
NNP	Net National Product
NPV	Net Present Value
NTFP	Non-timber forest product
NWA	National Wetland Atlas
NWCP	National Wetland Conservation Programme
OMFRA	Orissa Marine Fisheries Regulation Act
PEFC	Programme for Endorsement of Forest Certification
PES	Payments for Ecosystem Services
PF	Production Function
RC	Replacement Cost
REDD	Reducing Emissions from Deforestation and Forest Degradation
SAC	Space Application Centre
SACON	Salim Ali Center for Ornithology
SEEA	System of Environmental-Economic Accounts
SEEAF	System of Environmental and Economic Accounting for Fisheries
SNA	System of National Accounts
SOI	Survey of India
SPCB	State Pollution Control Board
TCM	Travel Cost Method
TEEB	The Economics of Ecosystems and Biodiversity
TEV	Total Economic Value
UK	United Kingdom
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO-MAB	United Nations Organization for Education, Science and Culture - Man and Biosphere Programme
UP	Uttar Pradesh
USA	United State of America
WISA	Wetlands International South Asia
WPA	Wildlife Protection Act
WTP	Willingness to Pay
WWF	World Wide Fund for Nature
ZSI	Zoological Survey of India

जयंती नटराजन
Jayanthi Natarajan

राज्य मंत्री (स्वतंत्र प्रभार)
पर्यावरण एवं वन मंत्रालय
भारत सरकार
नई दिल्ली-110 003
MINISTER OF STATE (INDEPENDENT CHARGE)
ENVIRONMENT & FORESTS
GOVERNMENT OF INDIA
NEW DELHI-110 003

FOREWORD

Nature and ecosystem services underpin our ability to lead a decent, healthy and secure life. In the recent decades, human beings have made unprecedented changes to the ecosystems to meet the ever increasing demand for food, freshwater and energy. While these changes have improved lives and livelihoods across the globe, they have also weakened nature's ability to provide several vital ecosystem services as regulation of hydrological regimes, protection against extreme events and purification of air and water. The declining wealth of our natural capital has direct economic repercussions, which are unfortunately underestimated. Making the value of natural capital visible to economies and society creates an evidence base to pave the way for more targeted and cost-effective solutions.

The Economics of Ecosystems Services and Biodiversity (TEEB) study initiated in 2007 marks an important effort towards increasing visibility of the value of ecosystem services and biodiversity in policy and decision making processes. Recognizing the significance of the study approach and outcomes, the Ministry of Environment and Forests initiated TEEB-India Project in February 2011 focused on economics of ecosystems services of wealth of our national natural resources and biodiversity. The assessments undertaken under the ambit of the project are ultimately aimed at providing policy specific recommendations at national, state and local levels to foster sustainable development and better conservation of ecosystems and biodiversity through the TEEB approach of recognizing, valuing and capturing ecosystem services.

Adopting a phased approach to implementation, coastal and marine ecosystems, inland waters and forests were prioritized for assessment of economics of ecosystem services and biodiversity. Following consultations with leading experts, academics and field practitioners, scoping reports were commissioned by the Ministry to assess the state of art of economics of the three ecosystems to develop a common and coherent assessment framework.

I am happy to note that the scoping phase has led to a synthesis of current knowledge of status and trends, conservation efforts, management challenges and state of application of economics approaches. These have been used to propose a methodological framework for further assessments for the three ecosystems. I am confident that this report will set the tone and directions for application of economic approaches to environmental policy making in the country, ultimately ensuring conservation of our rich biodiversity and its sustainable use. I also hope that the findings of this report are used by the various academic and research institutions to develop an interdisciplinary research programme on economics of ecosystem services across the country.

Jayanthi Natarajan

Jayanthi Natarajan

1 Introduction

Author
Kirit S Parikh (Chairman – IRADe, New Delhi
and Former Member, Planning Commission, Government of India)

Introduction

1. Importance of environment, ecosystem services and biodiversity in the Indian economy

The Indian economy needs to grow at 8% to 10% per year for two to three decades if India is to meet its development objectives. India's primary development objective is to have sustainable and inclusive growth that provides high level of well being to all its people.

Natural resources play a significant role in the lives of the poor who depend on them for their livelihood and sustenance. Maintaining the health of these ecological resources is vital to the well being of the poor. Natural resources contribute significantly to the GDP of poor.

Natural resources are important, not just for the poor, but for all people. The consequences of ecological destruction can be far reaching affecting lives of many at distant places and over time. Since some of the impacts take place gradually, one tends to neglect them.

Most economic activities have some environmental effect. When one drives a car, one creates air pollution. When a crop is grown, along with the crop produced, the soil quality changes. When the level of activities increases in an area, the environmental impacts are felt. While those who create the pollution do not pay for its full impact, others have to bear the burden. That is because the air pollution a car driver creates is not part of the profit and loss account of the driver. It is external to his considerations. Most problems of environment result from such externality and disregarded by the people who cause them. Particularly when they affect ecological functioning or biodiversity, the awareness of the damage one causes is little because the processes are slow and the impacts are not immediately visible. These impose huge cost on society.

For a country like India, where development is an imperative, such environmental consequences can be substantial and have to be faced all too frequently. If India is to meet its development objectives, it needs to set up power plants, mine coal, which is the major fuel resource, and set up industries. All these affect the environment, ecology and biodiversity. For example, development of hydropower cannot avoid ecological consequences. If a storage reservoir is created it may submerge forest. The flow pattern in the river changes and will affect aquatic flora and fauna. If, on the other hand, it is a run-off-the river scheme, water flow may dry up in the stretch of river between the weir from where water is diverted through a tunnel to a downstream power plant, which may be 10 kms away. Mining coal may also involve deforestation if the coal seams are below forest, as they mostly are in India. Similarly land and water required for industries and urbanization cause their own problem for the environment.

India's growing population and scarcity of land also put pressure on forest and wildlife habitats. Conflicts between wildlife and human settlement are common when elephants or leopards stray into human settlements.

This apparent conflict between environment and development must be faced. It can be resolved in a rational manner if one uses economics of environment, ecology and biodiversity. The benefits of development must be balanced against the costs of environment and ecological degradation. In assessing the costs one must consider the impact on the poor who may be particularly dependent on natural resources such as forest, water bodies and particular ecologies. Also social values and ethical considerations have to be brought in while resolving the conflicts. It is very important to assess and internalize the costs of loss of biodiversity and ecosystem services into all developmental projects, specially the ones related to infrastructure.

2. India's environmental policies

India has been very conscious of the importance of preserving its environment. Way back in 1970, even before the Stockholm Conference, India had set up National Committee for Environmental Planning and Coordination (NCEPC). India was one of the first countries in the world to set up a Ministry of Environment and Forests (MoEF).

Over the years many acts have been enacted to protect almost all aspects of environment. India has also been a signatory to all global pacts relating to environmental, ecological and biodiversity preservation.

For implementing the objectives of the various acts special institutions have also been created. Thus the Central Pollution Control Board (CPCB) has been set up at the national level, and so also State Pollution Control Board (SPCB) in each state. Industrial and development projects are required to prepare an environmental impact assessment (EIA) which has to be approved by the MoEF.

Apart from the impact on environment due to locally generated pollution, the threat of climate change from global emissions has also been of considerable concern to India as it is highly vulnerable to climate change. Thus Prime Minister's Council on Climate Change was set up in 2008, and it prepared the National Action Plan on Climate Change (NAPCC). It identified eight missions to address complex issues of adaptation and mitigation in a focused and targeted manner. Among these are: Green India Mission to expand forest coverage; Sustainable urban habitat mission; Himalayan ecosystem mission; Sustainable water use mission; National solar mission; Energy efficiency mission; and Sustainable agriculture mission. These missions will reduce stress on environment by reducing energy needs, promoting renewable resources and also by adapting to climate change.

Despite these acts, institutions and actions, the state of India's environment is not as good as one would like it to be. The effectiveness of many laws may be improved if economic instruments are used that create awareness and incentives for appropriate actions. Environmental externalities need to be internalized using 'polluter pays' principle. However, in order to do that one needs to assess the economic value of the externalities.

3. Economic valuation of environmental resources in India

The M.S. Swaminathan Committee set up to chalk out India's Action Plan for Environment recommended in 1989 that India should prepare natural resource accounts as a part of its national income accounts. Following this, MoEF asked the Indira Gandhi Institute of Development Research (IGIDR) to prepare a framework for such accounts (Parikh *et al*, 1993). At around that time the UN's Statistical Office had come out with framework for System of Environmental-Economic Accounts (SEEA.) This gave incentives to many researchers (a partial list is in the references) to prepare case studies of economic valuation for specific research and regions, see for example, Parikh and Parikh (1997,1998).

The Central Statistical Organization (CSO), which prepares India's national income accounts, commissioned in 2002 a number of research institutes to carry out integrated economics and environmental accounts for specific sectors and states. This was followed up by integration of these studies to prepare a road map to develop such accounts for the country (Murty and Panda, 2012).

Meanwhile another expert group was set up to suggest how India can have green accounts by 2015. This group's report is expected in coming months.

While India is well prepared to develop SEEA type accounts, these do not consider economic values of ecology and biodiversity adequately. Millennium Ecosystem Assessment has underscored the importance of ecosystem services and biodiversity, which are essential characteristic of ecosystems.

The interplay of elements of an ecosystem become even more complex when one considers them in a socio-economic context, as one must do for assessment of economic values. Annex 1.1 (Figures 1.1 and 1.2) illustrates this by showing human –forest interactions and the dynamics of forest resources inter-connections.

It is this complexity and importance of ecosystem and biodiversity that makes the TEEB project of great value to countries, particularly developing countries and particularly India with its diverse ecosystems and extensive biodiversity. Economic Valuation can provide invaluable guidance on policies for sustainable and inclusive development.

India ranks among the top ten species-rich nations and shows high endemism. With only 2.4% of global land area, India accounts for 7-8% of the recorded species of the world. The varied soil, climatic and topographic conditions and years of geological stability have resulted in a wide range of ecosystems and habitats such as forests, grasslands, wetlands, deserts, and coastal and marine ecosystem. India has four global biodiversity hot spots (Eastern Himalaya, Indo-Burma, Western Ghats and Sundaland). Besides, India is one of the eight Vavilovian centres of origin and diversity of crop plants, having more than 300 wild ancestors and close relatives of cultivated plants. India is also a vast repository of Traditional Knowledge associated with biological resources. An estimated 70% of India's population is dependent locally on natural ecosystems for subsistence means of livelihood, including fuel, housing, food, water and health.

Rapid industrial and economic growth in India, alongside with high dependence of people on natural resources for livelihoods has been putting tremendous stress on the natural ecosystems. India's National Biodiversity Action Plan, 2008 recognizes that threat to biodiversity stems mainly from habitat fragmentation, degradation and loss, shrinking genetic diversity, invasive alien species, declining forest resource base, climate change and desertification, overexploitation of resources, impact of development projects and impact of pollution.

Protecting biodiversity is a critical national priority for India linked to local livelihoods of millions of people in the country, thereby contributing to sustainable development and poverty reduction.

4. The Economics of Ecosystems and Biodiversity (TEEB)

A major reason for the degradation of ecosystem services and biodiversity is that their true values are not taken into consideration in economic decision making. At the meeting of the Environment Ministers of the G8 countries and the five major newly industrialising countries (Brazil, China, India, Mexico and South Africa) that took place in Potsdam, Germany in March 2007, the German government proposed a study on "The economic significance of the global loss of biological diversity" as part of the so-called "Potsdam Initiative" for biodiversity. This proposal was endorsed by G8+5 leaders at the Heiligendamm Summit on 6-8 June 2007. The German Federal Ministry for the Environment and the European Commission, with support of several other partners, jointly initiated this global study "The Economics of Ecosystems & Biodiversity (TEEB)". The TEEB Office is hosted by UNEP.

The TEEB study has been a major international initiative to draw attention to the global economic benefits of biodiversity, to highlight the growing costs of biodiversity loss and ecosystem degradation, and to draw together expertise from the fields of science, economics and policy to enable practical actions moving forward. The TEEB study compiled, built and made a compelling economics case for the conservation of ecosystems and biodiversity.

The TEEB Synthesis Report "Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB" was launched on the sidelines of the 10th meeting of the Conference of the Parties (COP 10) to the Convention on Biological Diversity (CBD), in Nagoya, Japan.

The Strategic Plan for Biodiversity 2011-2020 adopted by the COP 10 at Nagoya also recognizes the importance of valuation of ecosystems and biodiversity for achieving the strategic goal of "addressing the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society". The following three out of the 20 Aichi Biodiversity Targets establish the need for valuation of ecosystems and biodiversity:

> **Target 1:** By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.
>
> **Target 2:** By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems.
>
> **Target 3:** By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio economic conditions.

5. The TEEB-India process

Inspired by the international TEEB study, many countries have initiated or have shown interest in conducting TEEB studies at national, sub-national or regional levels. India has been amongst the first countries to launch a national TEEB study in Feb 2011. India has also set-up a high level expert committee on green national accounting.

The TEEB-India process aims to recognize and harness the economic valuation of biodiversity and ecosystem services. It targets action at the policy-making levels, the business decision level and the awareness of citizens.

Two national consultations involving expert ecologists, environmental economists, state governments, NGOs and international development organisations have been conducted in Feb 2011 and Sept 2011. These consultations have identified three major sectors, namely, forest ecosystems, inland wetlands and coastal and marine ecosystems, which are of high importance to India. It was also decided to get scoping studies done for each of this sector to help define roadmap and strategy for the TEEB-India process.

The present scoping studies therefore focus on three main sectoral areas:

i. Forest ecosystems
ii. Inland wetland ecosystems
iii. Coastal and marine ecosystems

These studies are presented in subsequent chapters. A brief summary of these is provided below.

5.1. Forest ecosystems

The scoping study (Ravindranath, Murthy and Mehra, 2012, Chapter 2) points out the importance of forest ecosystems, the types of ecosystem services provided, the importance of economic valuation and also the challenges involved in carrying out such studies.

In India, forests account for 21% of the geographic area and 200 million people live in and around forests, depending on it for their livelihoods. In India, many rivers originate in forests. The forest sector's contribution to GDP, though low (at 1.7% during 2011), could be high for the livelihood of forest dependent communities or poor in general. The role and contributions of forests is poorly understood and valued. Four of the of the 34 biodiversity hotspots of the world are located in India. Biodiversity hotspots are characterized both by exceptional levels of plant endemism and by serious levels of habitat loss.

The study discusses the ecosystem services and benefits and threats to them. Among the threats are forest conversion due to pressure from growing population and economic activities, non-sustainable extraction of timber and non timber forest products (NTFPs), livestock grazing, invasive alien species, mining, forest fragmentation and climate change. Among the biodiversity related services it discusses provisioning of fuel wood, fodder and manure, timber, NTFPs, medicinal plants and cultural services, tourisms and recreation. Among the regulating services are soil erosion prevention, flood control, water recharge and carbon sequestration.

Various valuation studies are reviewed and their limitations pointed out. Most studies assess only part of the production benefits and services of forest ecosystem and provide valuation of current flows. They do not cover future periods and do not value the possible impact on the stability of ecosystems. The study suggests that the target groups for the TEEB study should include, Ministry of Environment and Forests, Ministry of Finance, National Biodiversity Authority, Planning Commission, State Government Forest Departments, Gram Panchayats, Biodiversity Management Committees, Village Forest Committees, corporate sector both public and private, consumers and multilateral and bilateral agencies.

The study identifies the challenges that the TEEB India study would have to face. These include, scale and diversity of forest ecosystems; varied socio-economic status or pressures; methodological complexities; sampling size given the diversity of forest types and pressures; availability and access to data; networking of institutions and coordination; time line for the studies; and mainstreaming of TEEB in planning and policy making.

5.2. Inland wetland ecosystems

Ritesh Kumar and E.J. James (Chapter 3), have defined the scope of TEEB-India study on inland wetlands. India's inland wetlands as per the latest estimate cover 10.56 million ha. They exhibit enormous diversity from wetlands in the Himalayas, in the Ganges and Brahmaputra plains, in the Deccan Plateau and in the arid zones of Rajasthan and Gujarat. These wetlands support a range of floral and faunal diversity.

The total number of aquatic species in the country is known to exceed 1,200 species, reported to be an underestimate. The Zoological Survey of India (ZSI) has assessed the faunal diversity of Indian wetlands at 17,853 (19.9%) of 89,451 species occurring in India. These freshwater faunal elements are dominated by insects (about 5,000 species), molluscs and fishes (each representing about 2,000 species). The estimated figures are expected to increase many times, especially of micro invertebrates and parasitic groups, if these groups are extensively explored from all over Indian eco-regions. India ranks high in species endemism with 28,145 faunal species being endemic. A total of 223 fish species are endemic representing 8.75% of the fish species known to India and 127 monotypic genera representing 13.10% of the Indian genera of fishes. About seven avian species including Andaman Teal, Andaman Crake etc. are endemic to Indian wetlands. Endemic habitats are unique, and with changing climate, require exclusive management to conserve the biodiversity living therein. There are several wetlands which are hotspots of diversity.

The ecosystem services provided by inland wetlands include provisioning of fish, fruits, timber, fuel wood, fodder, medicines and genetic material; regulations of ground water recharge and discharge; pollution control and detoxification; flood control and storm protection; cultural activities of tourism, recreation and involving spiritual and inspirational feelings.

Though systematic data is not available, the inland wetlands are by and large shrinking. Fragmentation of hydrological regimes, catchment degradation, pollution, invasive species, area harvesting of resources and lack of awareness and participation are some of the causes of this shrinking. Economic valuation of select ecosystem services has shown significant values. It can provide a framework for putting in place effective management, conservation practices and institutions.

Valuation studies done in India have been few in number and thus cover only a small fraction of different types of wetlands. Most of them have valued provisioning services while regulating services have received almost no attention. Also, trade offs have been assessed by very few studies.

Methodologies which require validation of ecological relationships for determining ecosystem services (eg. production function, damage cost, replacement cost) in general have been under- emphasized. Again, this finding is related to the observation of lesser emphasis placed on valuation of regulating services of inland waters.

TEEB-India studies of inland wetlands have to fill many gaps of coverage, methodology and scope.

5.3. Coastal and marine ecosystems

Coastal and marine ecosystems are among the most productive ecosystems in the world and provide many services to human society and are of great economic value (UNEP 2006). Surrounded by the Indian Ocean, Arabian Sea and Bay of Bengal, the peninsular India has a coastline of about 8,100 km spanning nine maritime states and two union territories in the mainland, and two island union territories. The Exclusive Economic Zone (EEZ) extends to 2.02 million km^2 and the continental shelf area to 0.18 million km^2. The Indian coasts support about 30% of the total 1.2 billion human populations.

Indian coastal ecosystems comprising mudflats, sandy beaches, estuaries, creeks, mangroves, coral reefs, marshes, lagoon, sea grass beds, and sandy and rocky beaches extend about 42,808 km^2. They are known for their high biological productivity, which provides a wide range of habitat for many aquatic flora and fauna. The number of species in the coastal and marine ecosystems is suggested to be more than 13,000 (Venkataraman and Wafar 2005; MoEF 2009).

In spite of their ecological and economic importance and existence of policy and regulatory framework, India's coastal and marine ecosystems are under increasing threat. Overexploitation due to fishing, eutrophication from increased nutrient loading from agricultural runoff, sewage and fossil fuel burning, pressures from demographic, socio-political, cultural, economic and technological factors and climate change have led to degradation.

Many acts have been passed beginning with Indian Ports Act, 1908, Wildlife Protection Act, 1972, Marine Fishing Regulation Act, 1981 to the Biological Diversity Act, 2002.

In addition, India is signatory to a number of international conventions on biodiversity and ecology such as the UNCLOS and CBD, which include management of marine and coastal ecosystems. India is also a signatory to several international fisheries management instruments such as Ecosystem Approach to Fisheries (FAO) and the Indian Ocean Tuna Commission. These commitments have impact on India's management of its natural resources.

Among the ecosystem types in India are coral reefs, spread over 2,384 km^2, mangroves covering 4,462.26 km^2 in 2011, sea grass beds and seaweeds. From geographical perspective, the ecosystem types include beaches, sand dunes, earth cliffs, rocky cliffs, estuaries, lagoons, deltaic areas, salt marshes and islands.

Coastal and marine ecosystems provide all types of services, viz. provisioning, regulation, cultural and recreational and supporting services. Among the provisioning services fisheries and aquaculture are of considerable importance.

In India, marine fisheries contribute to nutritional security, livelihood and income generation to a large population. Census 2010 shows that 1.67 million fishermen are employed in the subsistence and industrial fishing sectors of the country. Marine fish landings in India consistently increased from 0.6 million tons (mt) in 1961 to 3.6 mt in 2011.

Economic valuation studies of coastal and marine ecosystems have generally looked at coral reefs and mangroves. The TEEB assessment can help meet conservation challenges by identifying policy implication for capturing and optimizing value, suggesting market-based instruments for effective implementation, providing guidance for corporate decision makers, indicating and showing ways of access and benefit sharing from bio-prospecting.

The TEEB study would have to face number of challenges. Setting base line, avoiding double counting, using appropriate valuation techniques and accounting for inter-temporal dynamics and stability of ecosystems and biodiversity are the major ones.

6. The way forward

These scoping studies have identified the importance, the issues, the scope and the challenges of economic valuation of ecosystems and biodiversity in three types of ecosystems of great relevance to India. To implement these, the following process would be followed:

A three-tier structure is being established to implement the TEEB-India project:

i. Steering Committee under the Chairmanship of Secretary (Environment and Forests) or Special Secretary
ii. Scientific and Technical Advisory Group comprising eminent ecologists and economists to guide and provide scientific and technical advice
iii. Expert Working Groups (one each for the three sectors) to undertake the TEEB assessments

A number of projects would be undertaken under each assessment to cover the diversity of India's ecosystems. TEEB-India study will require multi-disciplinary approach. There is a need to develop consistent methodology for assessing the economic value of biodiversity and ecosystem services to be used by different research teams to enable aggregation and comparison. There is a need to give adequate importance to both ecological as well as economic aspects of biodiversity and ecosystem services by involving both ecologists and economists in addition to sociologists, hydrologists, etc.

Next steps of the TEEB-India study would include the following:

- Set up a steering committee to provide overall guidance to the TEEB-India study
- Set up expert and technical advisory group to guide and supervise the TEEB-India study

- Set up expert working groups for TEEB-India assessment
- Define objectives and outputs of TEEB-India assessment
- Identify target groups for TEEB-India study outputs
- Stratify identified ecosystems for TEEB-India assessment
- Identify ecosystem services from the identified ecosystems
- Assess status of biodiversity and ecosystem services - focusing on assessing stocks, flows, change in ecosystem services and biodiversity across various scenarios of land use transformation and development of baseline scenario
- Develop indicators for each ecosystem service in the identified ecosystems
- Select methods and sampling procedures
- Conduct field studies, modeling and analysis
- Document successful case studies demonstrating application of valuation of ecosystem services
- Prepare target stakeholder-oriented TEEB-India reports
- Develop an approach to utilizing the knowledge of TEEB-India in planning, decision making, marketing, etc.

References

India State of Forest Report (ISFR), (2011). Forest Survey of India.

IRADe (2012), An outline for Measuring Ecosystem Services from Green India Mission: A case Study of Paderu Project in Andhra Pradesh , Integrated Research and Action for Development (IRADe).

MoEF (2009), India's Fourth National Report to the Convention on Biological Diversity. Ministry of Environment and Forests, Government of India, 156 pp.

Murty M N and Manoj Panda (2012), Generalizing National Income Accounts for Measuring Green GDP of India: A Review of Indian and International Experience CESS, Hyderabad.

Parikh, Jyoti and Kirit S. Parikh, Accounting and Valuation of Environment: A Primer for Developing Countries,. New York, United Nations, 1997.

Parikh, Jyoti and Kirit S. Parikh (eds) Accounting and Valuation of Environment: Case Studies from the ESCAP Region, New York, United Nations, 1998.

Parikh, Kirit S. Jyoti K. Parikh, V.K. Sharma and J.P. Painuly Natural Resource Accounting: A Framework for India, -prepared for MOEF, Indira Gandhi Institute of Development Research (IGIDR), November 1993.

Pearce, David and R.K. Turner (1990), Economics of Natural Resources and the Environment, John Hopkins University Press.

UNEP (2006), Marine and coastal ecosystems and human well-being: A synthesis report based on the findings of the Millennium Ecosystem Assessment. United Nations Environment Programme, 76 pp.

Venkataraman and Wafar (2005), Coastal and marine biodiversity of India. Indian Journal of Marine Sciences 34, 57-75.

References to Studies on Valuation of Environment in India

Chopra, K. and G. Kadekodi (1997): Natural Resource Accounting in the Yamuna Basin Accounting for Forest Resources, IEG Monograph, New Delhi.

Chopra K. and G. Kadekodi (1997): Natural Resource Accounting In The Yamuna Basin: Accounting For Forest Resources, IEG Monograph, New Delhi.

Chopra Kanchan and Adhikari Saroj Kumar (2002): Environment Development Linkages: Modelling A Wetland System for Ecological and Economic Value Institute of Economic Growth, Delhi.

Chopra, K (1993): The Value of Non-Timber Forest Products: An Estimation for Tropical Deciduous Forests in India, Economic Botany, Vol-47, No-3, Pp-251-257.

Datt Divya *et al.* (2006), Accounting for Unsustainable Mineral Extraction in Madhya Pradesh and West Bengal, Final Report Submitted to the Central Statistical Organization, Government of India, project report No. 2003 RD 62, The Energy and Resource Institute, Delhi.

Gupta, Usha (2007), Valuation of Urban air Pollution: A case Study of Kanpurnagar, Uttarpradesh, India, Ph.D Thesis, University of Delhi.

Haripriya, G. S. (2001), Accounting for the forest resources in the national accounts in India, Environmental and Resource Economics, Vol. 19(1), pp. 73-95.

Haripriya, G.S. (2000) Integrating Forest Resources into the System of National Accounts in Maharashtra, Environment and Development Economics, 5: 143-156.

Haripriya, G.S (2008), Environmental Accounting of Land and Water Resources in Tamilnadu, Final Report Submitted to the Central Statistical Organization, Government of India, Madras School of Economics, Chennai.

Misra, S. (1997): Measuring Benefits from Industrial Water Pollution Abatement: Use of Contingent Valuation Method in Nandesari Industrial Area of Gujarat in India, Working Paper no. E/185/97, Institute of Economic Growth, Delhi.

Misra, S. (1999): Water Pollution Abatement in Small-Scale Industries: An Exploration of Collective Action Possibilities in Nandesari Industrial Area in Gujarat, A PhD Thesis submitted to the University of Delhi, Delhi.

Murty, M. N, James, A. J., and Smita Mishra (1999), Economics of Industrial Pollution: Indian Experience, New Delhi: Oxford University Press.

Murty, M.N, and Surendar Kumar (2004), Environmental and Economic Accounting for Industry, New Delhi, Oxford University Press

Murty M.N and S.C. Gulati (2006) Natural Resource Accounts of Air and Water Pollution: Case Studies of Andhra Pradesh and Himachal Pradesh States of India, Final Report Submitted to the Central Statistical Organization, Government of India, Institute of Economic Growth, Delhi

Murty, M.N, Gulati, S.C. and Pitamber Chettri (2003), Valuation and Accounting of Urban Air Pollution in the Indian Subcontinent, Monograph, South Asian Network of Economic Institutions (SANEI)

Murty, M N, S C Gulati and A Banerjee (2003a), Health Benefits from Urban Air Pollution Abatement in the Indian Subcontinent, Working Paper No. E/236/2003, Institute of Economic Growth, Delhi

Murty, M.N, S.C. Gulati, and A. Banerjee, (2003b), `Hedonic Property Prices and Valuation of Benefits from Reducing Urban Air Pollution in India', Working Paper No. E 237/2003, Institute of Economic Growth, Delhi

Panchamukhi, P.R, Pushpa Trivedi *et al.* (2008), Natural Resource accounting in Karnataka: A Study of Land and Forestry Sectors, Final Report Submitted to the Central Statistical Organization, Government of India, Centre for Multi-displinary Development Research, Dharwad

Parikh, Jyoti *et al.* (2008), Natural Resource Accounting in Goa Phase II, Final Report Submitted to the Central Statistical Organization, Government of India, Integrated Research and Action for Development (IRADe), New Delhi.

Parikh Jyoti and Kirit Parikh, with the help of Vijay Laxmi Pandey, (1998) An Environmental Assessment of India.

Parikh Jyoti and Kirit Parikh, with the assistance of N. Hadker (1998), Solid Waste Management Accounts for India" .

Parikh Kirit and Jyoti Parikh, with the assistance of N. Satyanarayana Murthy, Sudhir Sharma, Nandini Hadker and Muraleedharan, (1998), Air Resource Accounts for India.

Reddy, Ratna (1999). Quenching the Thirst: The Cost of Water in Fragile Environments, Development and Change Vol 30 no. 1.

Roy Joyashree *et al.* (2008), Natural Resource Accounting for West Bengal: Sectors Air and Water, Final Report Submitted to the Central Statistical Organization, Government of India, Global Cahnge Programme, Jodavpur University, Kolkata.

Singh O.P *et al.* (2008), Environmental Accounting of Natural Resources of Meghalaya: Land and Forest Resources, Final Report Submitted to the Central Statistical Organization, Government of India, Centre for Environmental studies, North-eastern Hill University, Shillong.

TERI. (1994) Accounting for coal depletion in the national income accounts of India; Natural Resource Accounting - A Means to Measure Sustainable Development in India New Delhi: The Energy and Resources Institute

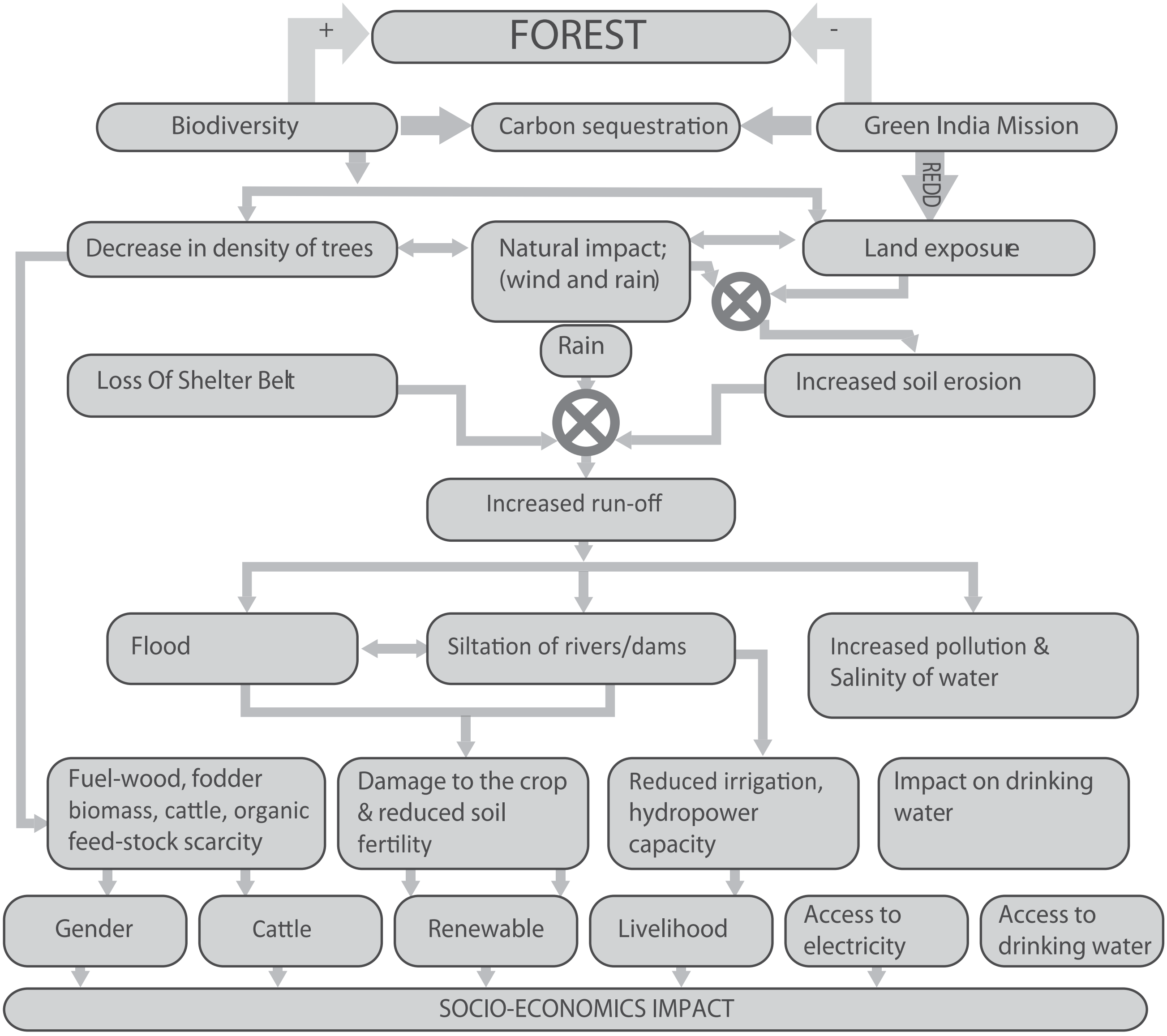
Venkatachalam, L., (2000) Economic Valuation of Water Used in the Household Sector: A Contingent Valuation Approach in a Developing Country Context, Thesis submitted for the Degree of Doctor in Philosophy in Economics, University of Madras, Chennai

Verma, Madhu and CVRS Vijaykumar (2006), Natural Resource accounting of Land and Forest Sector for the States of Madhya Pradesh and Himachal Pradesh, Indian Institute of Forest Management, Bhopal.

Annexure

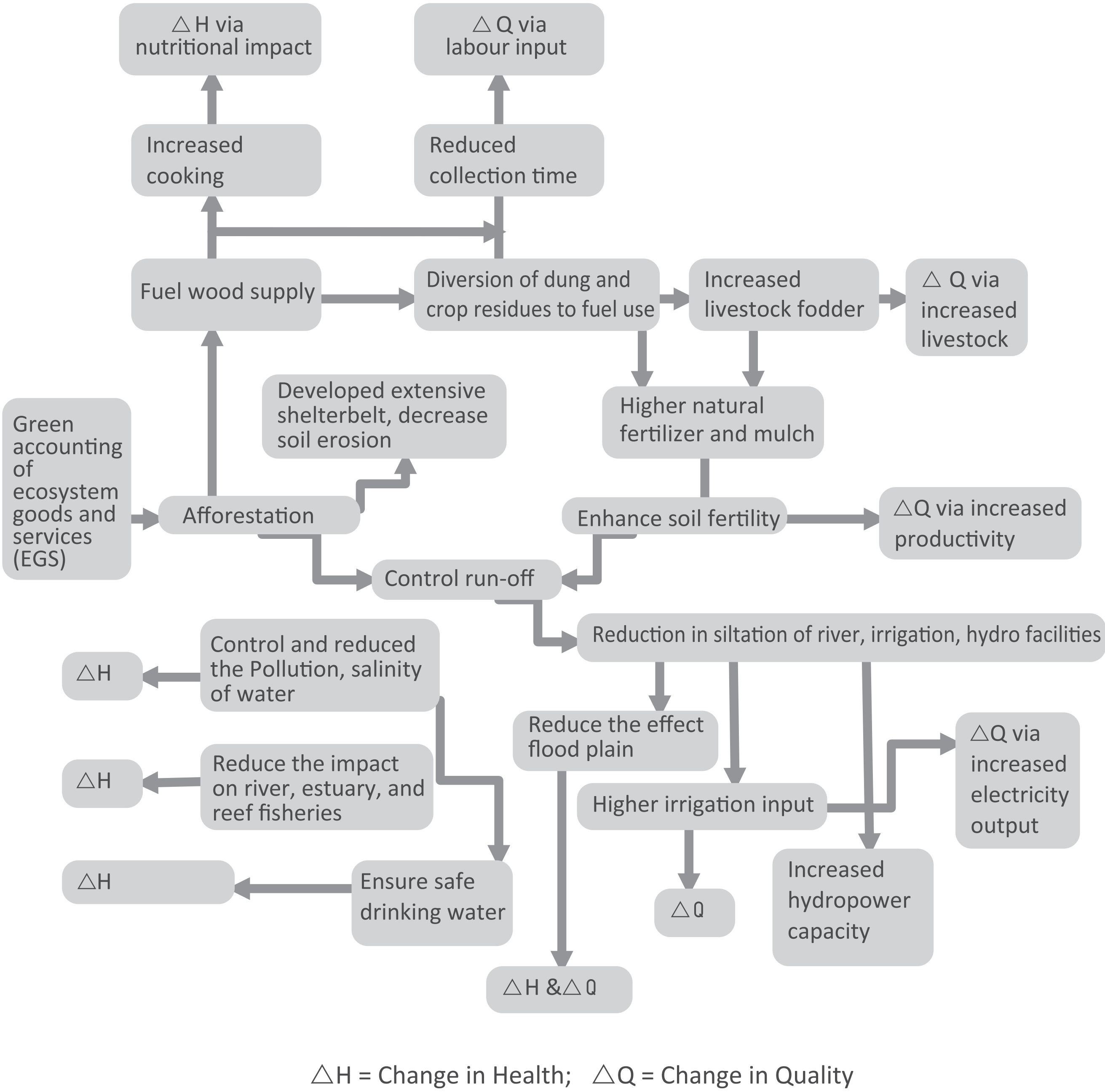
1.1. Interactions and inter-connections of forest ecosystems

Figure 1.1 Human- Forest Interaction



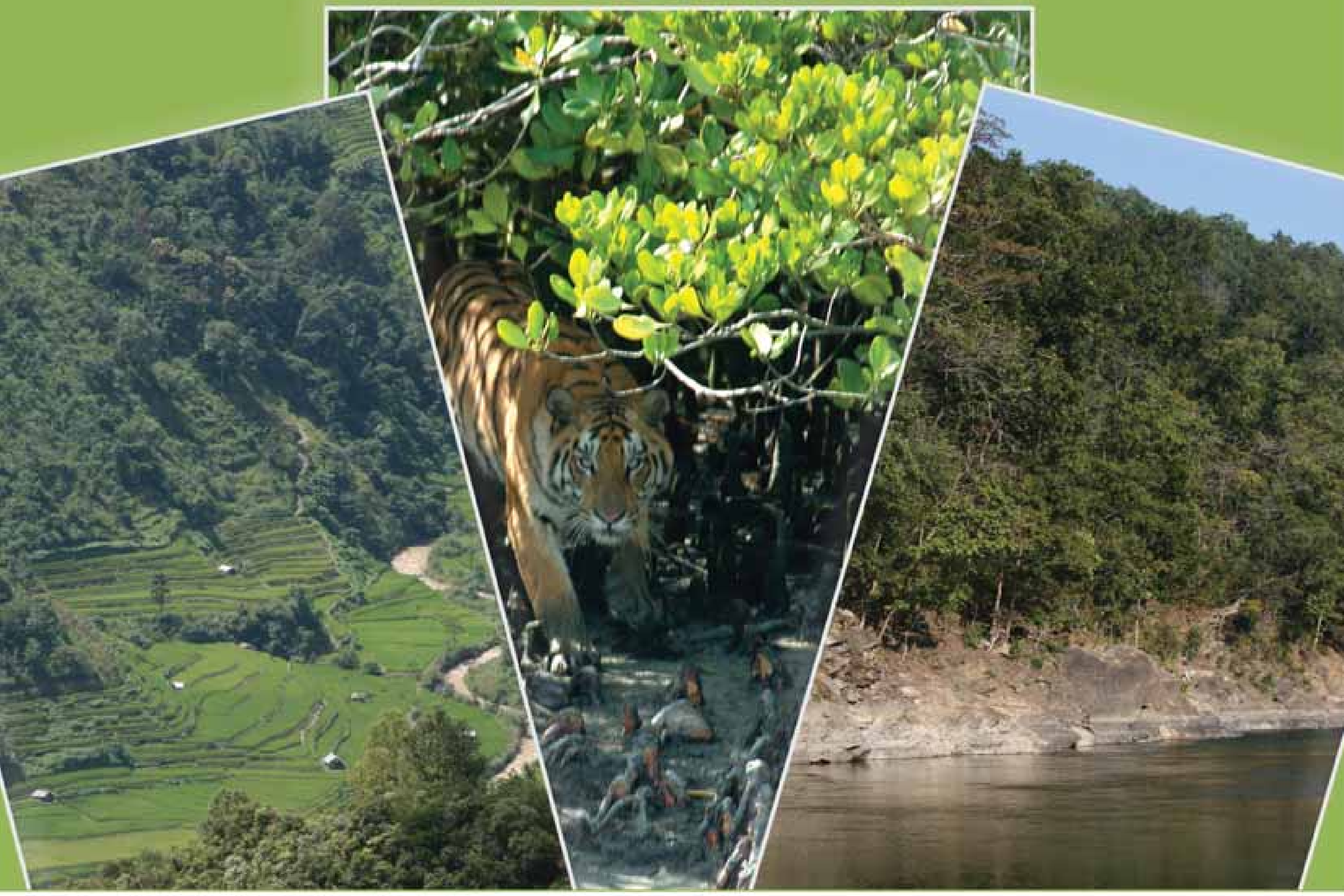
Source: Compiled by IRADe, 2012

Figure 1.2 Forest Resources Inter-connection



Source: Prepared by IRADe (2012) based on Pearce and Turner (1990)

2 Forest Ecosystems



Lead Authors
N H Ravindranath (Indian Institute of Sciences, Bangalore)
Indu K Murthy (Indian Institute of Sciences, Bangalore)
Swapan Mehra (Iora Ecological Solutions, New Delhi)

Contributing Authors
Devathi Parashuram, Mohini Gupta and Sonam Tomar

Contents

1. Overview of the Extent and State of Forest Ecosystems in India

1.1. Area under forests and changes in forest area

Forest resources have an important bearing on the environmental/ecological security and well-being of the country and people (ISFR, 2011). The importance of forests as a natural resource has been recognized by the Government of India and therefore large emphasis has been laid on the conservation, restoration and development of forests. The Forest Survey of India (FSI) defines forest as, "all the lands, more than one hectare in area, with a tree canopy density of more than 10%". The area under forests in India according to the State of Forest Report (ISFR, 2011), that is published periodically since 1987, is 69.20 Mha, accounting for about 21% of the total geographic area of India, of this, about 2.5% is very dense forest, about 10% is moderately dense, about 9% is open forest and scrub accounts for 1.2% (Figures 2.1 and 2.2).

Table 2.1 presents the net area under forests in India during the period 1985-87 to 2007-09. Data in Table 2.1 shows that the forest area in India is generally stable and consistently increasing since 1995-97.

Figure 2.1. Forest cover of India according to density class (ISFR, 2011)

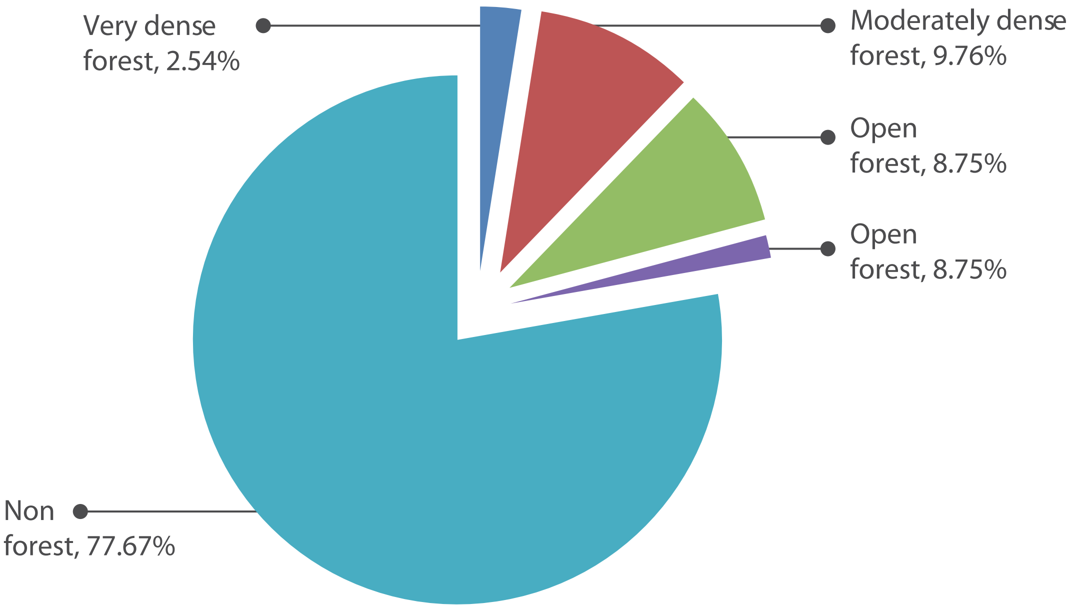


Table 2.1. Net area (Mha) under forests at different time periods

Forest type	Year of assessment							
	1985-87	1995-97	1997-99	1999-01	2001-03	2003-05	2005-07	2007-09
Dense	36.14	36.73	37.74	41.68	39.06	38.72	40.25	40.42
Open	28.16	26.61	25.99	25.87	28.78	28.99	28.84	28.78
Total	64.20	63.34	63.73	67.55	67.83	67.71	69.09	69.20

Figure 2.2. Forest cover of India (ISFR, 2011)

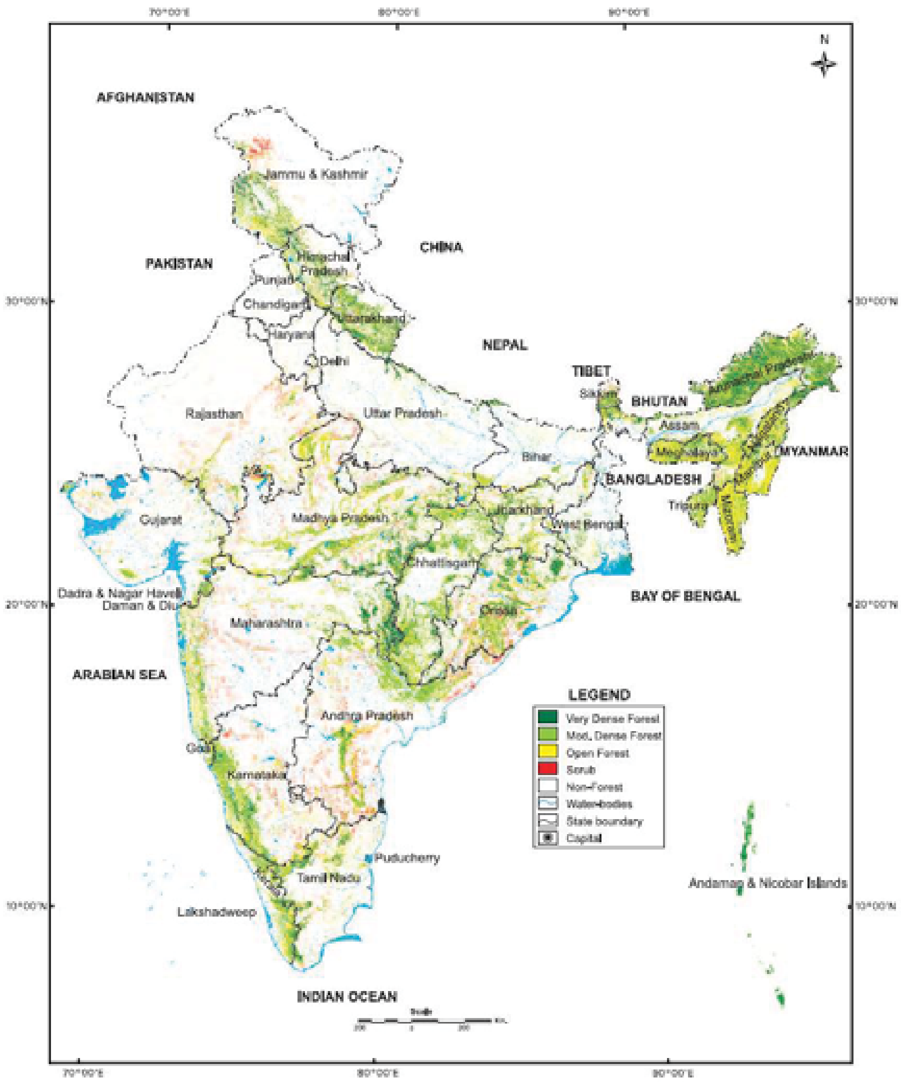


Table 2.2 presents the forest cover change matrix for the period 2007 to 2009 as reported by ISFR (2011). As can be seen from Table 2.2, a net increase in very dense and moderately dense forest is reported. The recent assessment reveals that there is an increase of 49,800 ha of moderately dense forest and 4,300 ha of very dense forest category (ISFR, 2011) during 2007-2009. The increase in area under denser forest types may not necessarily mean improvement in forest biodiversity and ecosystem services, due to predominance of monoculture dominated tree plantations in the afforestation programmes in India.

Table 2.2. Forest cover change matrix for India between 2007 and 2009 (in ha)

Class	VDF	MDF	OF	Scrub	NF	Total of 2007
VDF	8,313,300	22,900	2,100	0	4,500	8,342,800
MDF	31,100	31,605,400	190,300	8,100	188,800	32,023,800
OF	2,000	292,900	28,191,700	45,500	340,600	28,872,800
Scrub	0	8,200	48,800	4,130,500	17,500	4,205,000
NF	700	144,200	349,100	33,500	254,754,500	255,282,000
Total of 2009	8,347,100	32,073,600	28,782,000	4,217,600	255,306,000	328,726,300
Net change	**4,300**	**49,800**	**-90,800**	**126**	**240**	

VDF: Very Dense Forest, MDF: Moderately Dense Forest, OF: Open Forest, NF: Non-Forest
Source: ISFR, 2011

1.2. Forest cover in hill districts

The National Forest policy (1988) aims at maintaining 2/3rd of the geographic area in hill states under forest and tree cover. In India there are 124 hill districts, accounting for about 40% of the total geographic area. The forest cover in the hill districts is 28.12 Mha.

1.3. Change in forest cover and reasons for change

The state of forest report (ISFR, 2011) presents state-wise changes in forest cover during the period 2007 to 2009. The overall change in forest cover at the national level is a loss of 36,700 ha with states like Andhra Pradesh, Manipur, Nagaland, Arunachal Pradesh, Mizoram and Meghalaya accounting for most of the loss. Conversely some states like Punjab, Jharkhand, Tamil Nadu, Andaman and Nicobar, Rajasthan and Orissa report positive changes in forest area. The key factors resulting in loss of forest cover in some of the states include, harvest of short rotation plantations, forest clearances in some encroached areas, shifting cultivation, biotic pressures, illicit felling and encroachments (ISFR, 2011).

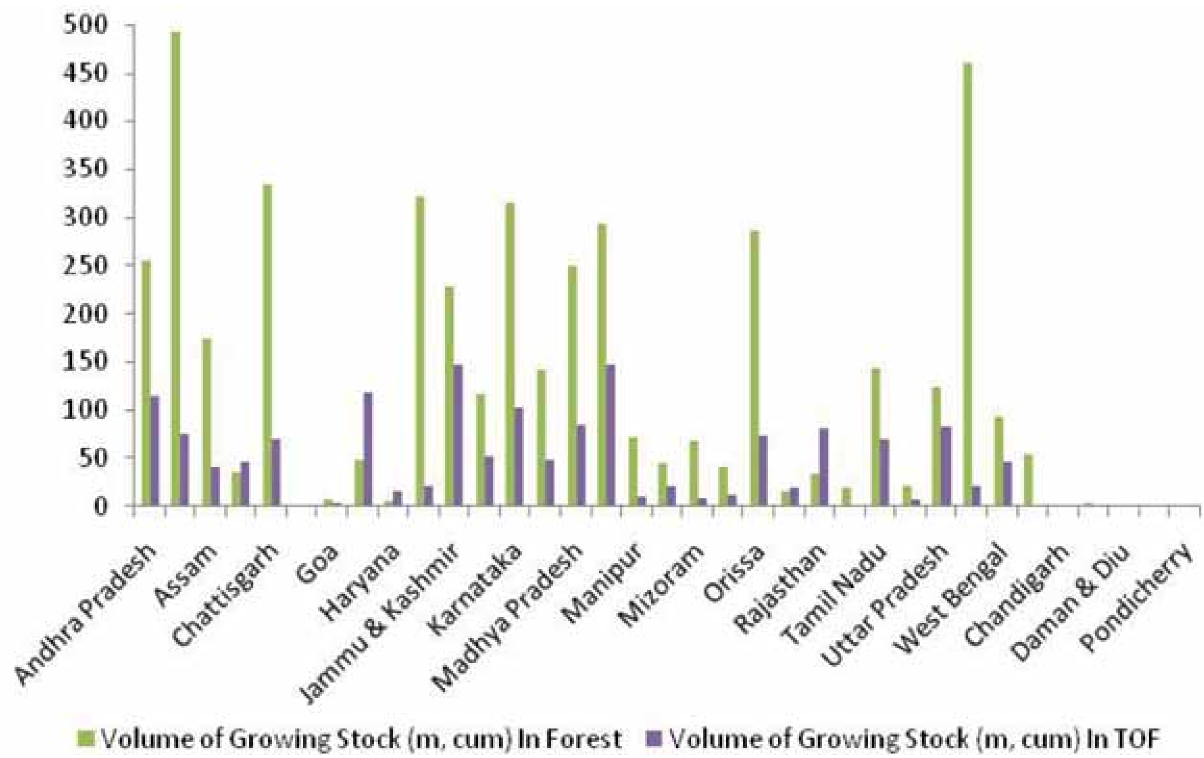
1.4. Tree cover

Tree cover comprises tree patches with an area less than one hectare but a minimum of 0.1 ha and outside the recorded forest area (ISFR, 2011). The total tree cover in India is estimated to be 9.08 Mha, accounting for about 3% of the total geographic area of the country. Area estimates according to states as well as physiographic zones are presented in ISFR (2011).

1.5. Growing stock and carbon estimates

Growing stock: Estimates of growing stock as an indicator of forest health and productivity are presented in the state of forest report (ISFR, 2011) according to physiographic zones as well as states. Among the different states and union territories (Figure 2.3), the growing stock in Arunachal Pradesh is highest, followed by Uttarakhand and Chhattisgarh. In trees outside forest, maximum growing stock has been recorded on Jammu & Kashmir followed by Maharashtra and Gujarat. The growing stock estimates according to physiographic zones is available only for trees outside forest in the current assessment report (ISFR, 2011) and it is highest in East Deccan followed by Western Himalayas and the West Coast.

Figure 2.3. State-wise growing stock estimates in forest and trees outside forests of India

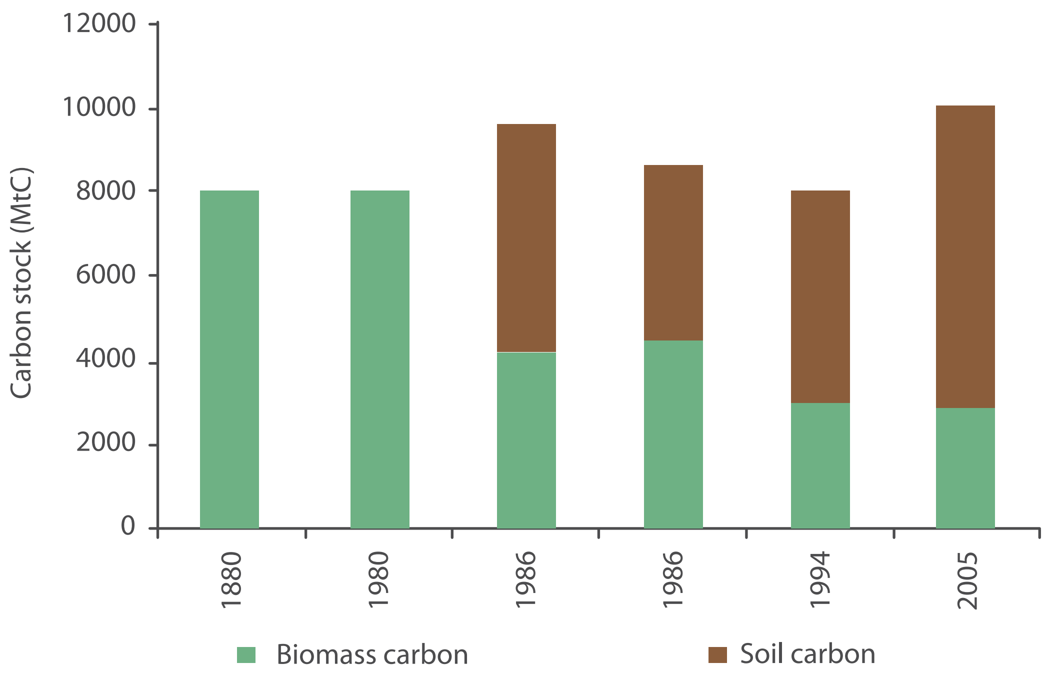


Carbon: ISFR (2011) presents carbon stock estimates for all the five carbon pools viz., aboveground biomass, belowground biomass, litter, deadwood and soil and for both forestland remaining forestland as well as land converted to forestland. The carbon stock in forestland remaining forestland during 2004 as estimated by ISFR (2011) is 6,288 Mt (Table 2.3). The carbon stock in land converted to forest land for the same period is estimate to be 375 Mt. Overall, the total carbon stocks considering both forestland remaining forestland as well as land converted to forestland is 6,663 MtC. Pool-wise carbon estimates is presented in Table 2.3. Estimates of carbon stocks in biomass and soil are presented in Figure 2.4, as compiled by Ravindranath *et al* (2008).

Table 2.3. Change in carbon (C) stock from forest land remaining forest land including land converted to forest land

Component	C stock in forest land in 1994 (MtC)	C stock in forest land remaining forest land in 2004 (MtC)	Net change in C stock in forest land remaining forest land (MtC)	Annual change in C stock in forest land remaining forest land during 1994-2004 (MtC)	C stock change from land converted to forest land in 2004 (MtC)	Annual change in C stock in forest lands 1994-2004 (MtC)
Above ground biomass	1,784	1,983	199	19.9	118	11.8
Belowground biomass	563	626	63	6.3	37	3.7
Deadwood	19	24	5	0.5	1	0.1
Litter	104	114	10	1	7	0.7
Soil	3,601	3,542	-59	-5.9	211	21.1
Total	**6,071**	**6,288**	**217**	**21.7**	**375**	**37.5**

Figure 2.4. Biomass and soil carbon estimates in forests in India (Ravindranath et al., 2008)



1.6. Status of biodiversity

India has been recognized as one of the mega diverse countries of the world (Mittermeier et. al., 2001) having only 2.4% of world's land area. There are about 1.7 million species in the world that have been discovered and still many more are yet to be discovered. Out of which India has about 7-8% of the species that includes 45,500 floral species and 91,000 faunal species (NBAP, 2008). India is placed at seventh position in terms of richness of mammalian species, ninth for birds and fifth for reptiles. With reference to endemic species, India ranks tenth for avian species with 69 species, fifth for reptiles with 156 species and seventh for amphibians with 110 species. India's share in world's crop biodiversity is 44% (India's Fourth National Report to CBD, 2009).

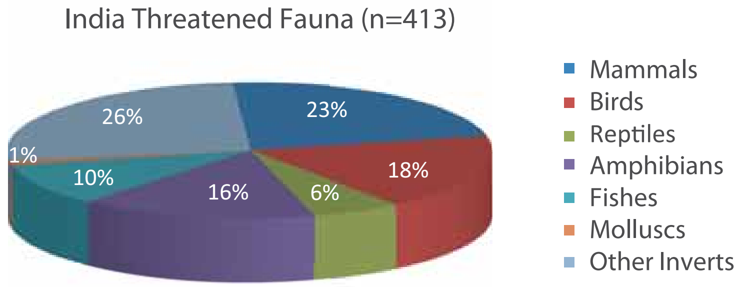
India's faunal diversity: India accounts for 7.43% of world's faunal species. Various faunal groups show range of endemism in India. Some of the lower groups such as *Mesozoa* (100%), *Acanthocephala* (88.6%), *Oligochaeta* (77.8%), and *Platyhelmithes* (71.9%) show high degree of endemism. As per IUCN Red list (2008), India also houses 4.9% of world's total threatened species i.e., about 413 species (Figure 5) (India's Fourth National Report to CBD, 2009). The number of threatened faunal species in different categories which are listed in the WPA and the Appendices of CITES, and Convention on Migratory Species (CMS) are given in Table 2.4.

Table 2.4. Threatened Indian species listed in WPA and appendices of CITES and CMS

Group	Schedules of IWPA					Appendices of CITES			Appendices of CMS		
	I	II	III	IV	V	I	II	III	I	I/II	II
Mammals	16	6	1	-	-	56	31	5	4	4	10
Birds	10	-	-	23	-	87	55	5	4	18	-
Reptiles	10	-	-	1	-	10	8	-	1	4	-
Amphibia	18	11	-	28	-	-	-	-	-	-	-
Pisces	-	2	-	-	-	-	3	-	-	-	-
Crustacea	-	-	-	-	-	-	-	-	-	-	-
Mollusca	3	-	-	-	-	-	-	-	-	-	-
Hymenoptera	-	-	-	-	-	-	-	-	-	-	-
Lepidoptera	-	-	-	-	-	-	-	-	-	-	-
Odonata	1	-	-	-	-	-	-	-	-	-	-
Anoplura	-	-	-	-	-	-	-	-	-	-	-
Total	58	19	1	52	-	153	97	10	9	26	10

Source: www.wii.gov.in/indianfauna/globally%20threatened%20indian%20fauna.pdf

Figure 2.5. Threatened fauna in India



India's floral diversity: India represents about 11% of world's total floral diversity having nearly 45,500 plant species. With such plant diversity, India ranks tenth in the world and fourth in Asia. Table 2.5 shows India's share of world's flora.

Table 2.5. Recorded plant taxonomic groups in India and percentage share in world flora

Taxonomic group	No. of species	% of world flora
Angiosperms	17,527	7.0
Gymnosperms	67	10.3
Pteridophytes	1,200	12.0
Bryophytes	2,500	17.2
Lichens	2,223	16.4
Fungi	14,500	20.1
Algae	7,175	17.9
Virus/Bacteria	850	10.6

Source: BSI, 2009, for further information regarding country, state or district -wise distribution of various plant species refer to http://www.nbri.res.in/padap/.

There are about 11,058 species which are endemic to India out of which 6,200 species belong to Angiosperms. The regions that show abundance of these endemic species include eastern Himalayas and north-eastern region (2,500 species), peninsular India including Western and Eastern Ghats (2,600 species), north-west Himalayas (800 species) and Andaman and Nicobar islands (250 species). Table 2.6 shows number of endemic species of various plant groups in India.

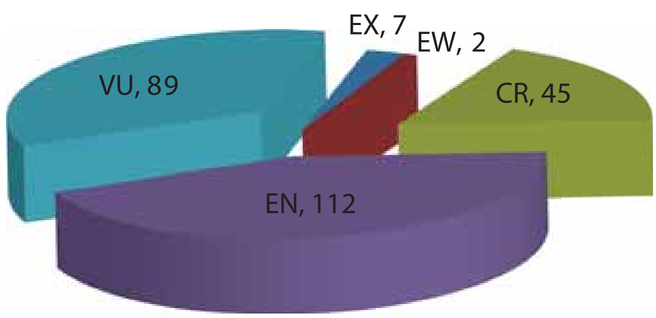
Table 2.6. Endemism of different plant groups in India

Plant group	Total no. of species in India	No. of endemic species	Percentage
Angiosperms	17,527	6,200	35.3
Gymnosperms	67	7	14.9
Pteridophytes	1,200	193	16.0
Bryophytes	2,500	629	25.1
Lichens	2,223	527	23.7
Fungi	14,500	3,500	24.0
Algae	7,175	1,925	26.8

Source: BSI, 2009

According to IUCN Red List (2008), India's share in world's total threatened floral population is 2.9% i.e. 246 species. Figure 2.6 shows distribution of various vulnerable (VU), endangered (EN), critically endangered (CR), extinct in the wild (EW), and extinct (Ex) species in India.

Figure 2.6. Threatened plant species in India according to IUCN red list



Biodiversity hotspots: Biodiversity hotspots are characterized both by exceptional levels of plant endemism and by serious levels of habitat loss (Norman Myers, 1988). To qualify as a hotspot, a region must meet two strict criteria; i) it must contain at least 1,500 species of vascular plants (> 0.5 percent of the world's total) as endemics, and ii) it has to have lost at least 70 percent of its original habitat. Two of the of the 34 biodiversity hotspots of the world are located in India (Eastern Himalayas and the Western Ghats).

Eastern Himalayan Hotspot: The world's highest mountain, including Mt. Everest resides in the Himalayan hotspot. The mountain range has a great diversity of ecosystems ranging from alluvial grasslands and subtropical broadleaf forests to alpine meadows above the tree line. Vascular plants have even been recorded at height as high as 6,000 meters. Various species of large birds and mammals, including vultures, tigers, elephants, rhinos and wild water buffalo are found here. It is unique in itself because of high endemism (40%) of species. Table 2.7 describes richness of biodiversity in Himalayan hotspot.

The Western Ghats: The Western Ghats runs along the west coast of India. It serves as home for many endemic species of plants, reptiles and amphibians. Table 2.8 shows the biodiversity richness in the Western Ghats.

Table 2.7. Biodiversity in Himalayan hotspot

Taxonomic group	Species number	Number of endemic species	% of endemism
Vascular plants	10,000	3,160	31.6
Mammals	300	12	4
Birds	979	15	1.53
Reptiles	177	49	27.68
Amphibians	105	42	40
Freshwater fishes	269	33	12.26

Source: http://www.biodiversityhotspots.org

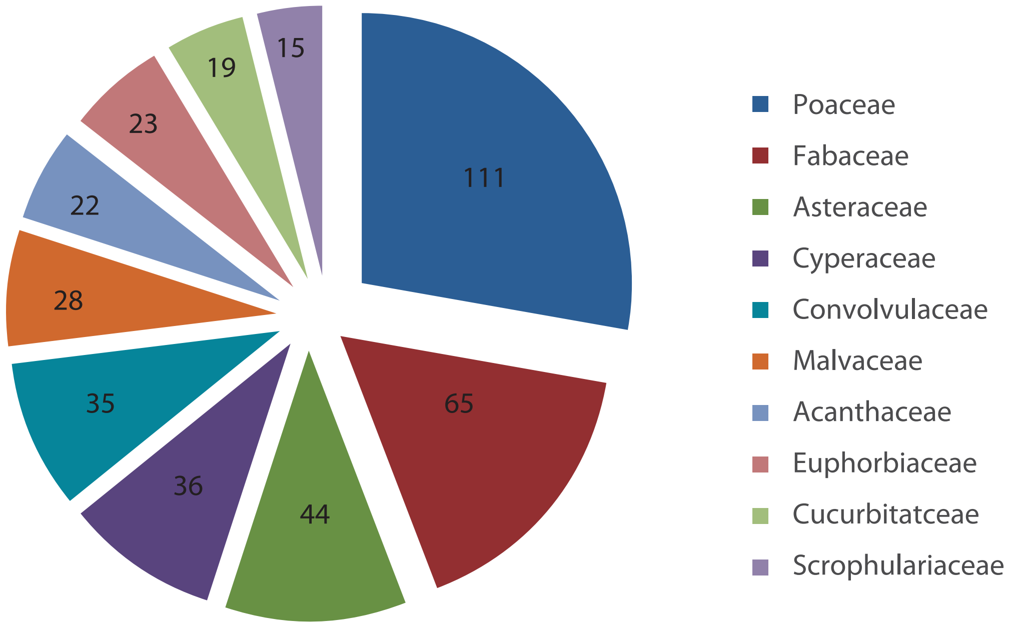
Table 2.8. Biodiversity in the Western Ghats

Taxonomic group	Species	Endemic species	% of endemism
Angiosperms	4,000	1,500	38
Butterflies	332	37	11
Fishes	288	116	53
Amphibians	156	94	78
Reptiles	225	97	62
Birds	508	19	4
Mammals	137	14	12

Source: http://www.wii.gov.in/envis; ZSI 2008

Biodiversity of arid and semi-arid lands: 38.8% (127.3 Mha) of total geographic land area comprises arid and semi-arid regions of India, covering 10 major states such as Rajasthan (60%), Gujarat (20%), Punjab and Haryana (9%) and Andhra Pradesh, Karnataka and Maharashtra (10%). There are about 682 species (352 genera and 87 families; 86 angiosperm and 1 gymnosperm family) found in Indian desert. Out of these, 8 families, 37 genera and 63 species were introduced there. Figure 2.7 presents ten largest families with maximum species diversity in Indian deserts.

Figure 2.7. Ten largest families with maximum species diversity in Indian deserts



1.7. Biodiversity information base

In India 70% of the land area has been surveyed and about 45,500 plant species and 91,000 animal species have been described (NBAP, 2008). It is estimated that about 4,00,000 more species may exist in India which are yet to be recorded and described. Currently the baseline data on species and genetic diversity, and their macro-and micro-habitats, is inadequate. In India a large number of organizations/agencies are working on various aspects of biodiversity, but the information on the subject is scattered and not yet integrated into a national database. Some of the databases being developed are not according to the standard, mainly due to lack of infrastructure, skilled manpower and coordination among experts in different fields. There is a need for a uniform format for collection, retrieval and dissemination of data. The underground biodiversity, particularly soil microbes, are even less poorly understood. Similarly, the microbial diversity of fresh water and marine ecosystems is less known.

2. Forest Ecosystem Types in India

Climate is one of the most important determinants of vegetation patterns globally and has significant influence on the distribution, structure and ecology of forests (Kirschbaum *et al.*, 1995). An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. Humans are an integral part of ecosystems. Forests can be classified in different ways. The forest type depends upon the abiotic factors such as climate and soil characteristics of a region. Forests in India can be broadly divided into coniferous and broadleaved forests. They can be classified according to the nature of their tree species - evergreen, deciduous, xerophytes or thorn trees, mangroves, etc. They can also be classified according to the most abundant species of trees, such as Sal or Teak forests. Features of different forest types are as follows:

- Broad-leaved forests are of several types, such as evergreen forests, deciduous forests, thorn forests, and mangrove forests.
- Evergreen forests grow in the high rainfall areas of the Western Ghats, North –eastern India and the Andaman and Nicobar Islands. These forests grow in areas where the monsoon period lasts for several months.
- Deciduous forests are found in regions with a moderate amount of seasonal rainfall that lasts for only a few months. Most of the forests in

which Teak trees grow are of this type. The deciduous trees shed their leaves during the winter and hot summer months.

- Thorn forests are found in the semi-arid regions of India. The trees, which are sparsely distributed, are surrounded by open grassy areas.
- Mangroves forests grow along the coast especially in the river deltas.

2.1. Forest types in India

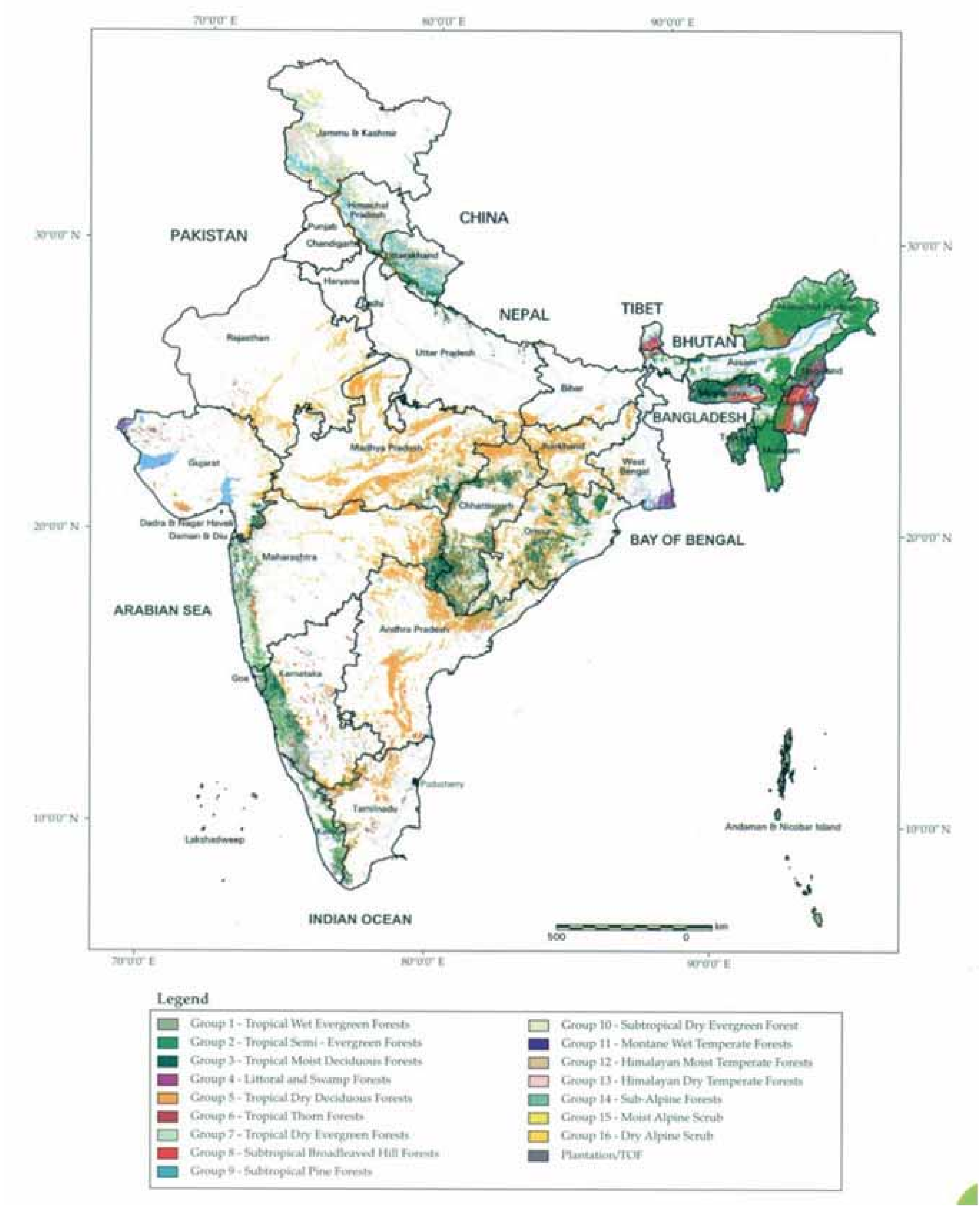
India has a diverse range of forests from the rainforest of Kerala in the south to the alpine pastures of Ladakh in the north, from the deserts of Rajasthan in the west to the evergreen forests in the north-east. Forests are classified according to their nature and composition, the type of climate in which they thrive, and its relationship with the surrounding environment.

Champion & Seth system of classification (1968) provides an elaborate description of forest types of India in six major groups which are further divided into 16 type groups (Table 2.9) and finally into 200 types including subtypes and variations of forests. The 'forest type' may be defined as a unit of vegetation with distinctive physiognomy and structure. As per Champion & Seth, the determining factors of the forest types are climate, soil, vegetation and the past treatment (including biotic interference). The forest type map of India is presented in Figure 2.8.

Table 2.9. Forest type groups according to Champion and Seth and their distribution in India

Forest type group	
Moist tropical Forests	
Group 1- Wet evergreen	Found in the south along the Western Ghats and the Nicobar and Andaman Islands and all along the north-eastern region.
Group 2 - Semi-evergreen	Found in the Western Ghats, Andaman and Nicobar Islands, and the Eastern Himalayas.
Group 3 - Moist deciduous	Found throughout India except in the western and the north-western regions.
Group 4 - Littoral and swamp	Found along the Andaman and Nicobar Islands and the delta area of the Ganga and the Brahmaputra.
Montane sub tropical Forests	
Group 8 - Broad leaved	Found in the Eastern Himalayas and the Western Ghats, along the Silent Valley.
Group 9 - Pine	Found in the steep dry slopes of the Shivalik Hills, Western and Central Himalayas, Khasi, Naga, and Manipur Hills.
Group 10 - Dry evergreen	Found in the Shivalik Hills and foothills of the Himalayas up to a height of 1000 metres.
Dry tropical Forests	
Group 5 - Dry deciduous	Found throughout the northern part of the country except in the North-East. It is also found in Madhya Pradesh, Gujarat, Andhra Pradesh, Karnataka, and Tamil Nadu.
Group 6 - Thorn	Found in areas with black soil: North, West, Central, and South India.
Group 7 - Dry evergreen	Found along the Andhra Pradesh and Karnataka coast.
Montane temperate Forests	
Group 11 - Wet	Occur in the North and the South. In the North, it is found in the region to the east of Nepal into Arunachal Pradesh, at a height of 1800–3000 metres, receiving a minimum rainfall of 2000 mm. In the South, it is found in parts of the Nilgiri Hills, the higher reaches of Kerala.
Group 12 - Moist	Spreads from the Western Himalayas to the Eastern Himalayas.
Group 13 - Dry	Found mainly in Lahul, Kinnaur, Sikkim, and other parts of the Himalayas.
Group 14 - Sub alpine forests	
Alpine Forests	
Group 15- Moist	Found all along the Himalayas and on the higher hills near the Myanmar border.
Group 16- Dry	Found from about 3000 metres to about 4900 metres

Figure 2.8. Forest type map of India (ISFR, 2011)



2.2. Forest cover in different forest types

The State of Forest Report (2011) has for the first time mapped area according to forest types, following the Champion and Seth forest type classification (1968). Table 2.10 presents percentage area under different forest types according to Champion and Seth forest type groups.

Table 2.10. Forest cover in different forest type groups

Forest type group	% of forest cover
Tropical wet evergreen	2.92
Tropical semi-evergreen	13.79
Tropical moist deciduous	19.73
Littoral and swamp	0.69
Tropical dry deciduous	41.87
Tropical thorn	2.25
Tropical dry evergreen	0.13
Sub-tropical broadleaved hill	2.69
Sub-tropical pine	2.63
Sub-tropical dry evergreen	0.03
Montane wet temperate	0.69
Himalayan moist temperate	4.121
Himalayan dry temperate	0.84
Sub-alpine and alpine forest	2.55
Plantation and trees outside forests	5.07

Maximum area is under tropical dry deciduous forest (about 42%), followed by tropical moist deciduous (about 20%) and tropical semi-evergreen forest types (about 14%). Himalayan moist temperate forest accounts for about 4% while sub-tropical broadleaved hill forests, sub-tropical pine and sub-alpine and alpine forests account for about 3% of the total forest cover.

3. Ecosystem Services

Ecosystem services are the benefits that people obtain from ecosystems. Some ecosystem services are well known, such as those which are essential for life (e.g. food and clean air and water) or those which improve our quality of life (e.g. recreation and beautiful landscapes). Other services are often taken for granted, such as natural processes (e.g. pollination and flood regulation).

The Millennium Ecosystem Assessment (MA, 2005) considers humans as an integral component of the natural ecosystem unlike classical approaches, which differentiate humans as non-natural. The approach also addresses the sustainability of resources and livelihoods by considering human wellbeing a parallel theme to the functioning of the natural ecosystem.

Figure 2.9 outlines ecosystem services from forest ecosystems. The MA (2005) categorized ecosystem services into four classes:

- Provisioning services
- Regulating services
- Cultural services
- Supporting services

Provisioning Services: These are products obtained from ecosystems, including:

- Food and fiber. This includes the vast range of food products derived from plants, animals, and microbes, as well as materials such as wood, jute, hemp, silk, and many other products derived from ecosystems.

- Fuel. Wood, dung, and other biological materials serve as sources of energy.
- Genetic resources. This includes the genes and genetic information used for animal and plant breeding and biotechnology.
- Biochemicals, natural medicines, and pharmaceuticals. Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems.
- Ornamental resources. Animal products, such as skins and shells, and flowers are used as ornaments, although the value of these resources is often culturally determined.

Regulating Services: These are the benefits obtained from the regulation of ecosystem processes, including:

- Air quality maintenance. Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality.
- Climate regulation. Ecosystems influence climate both locally and globally. For example, at a local scale, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.
- Water regulation. The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.
- Erosion control. Vegetative cover plays an important role in soil retention and the prevention of landslides.
- Water purification and waste treatment. Ecosystems can be a source of impurities in fresh water but also can help to filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems.
- Regulation of human diseases. Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.
- Biological control. Ecosystem changes affect the prevalence of crop and livestock pests and diseases.
- Pollination. Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.
- Storm protection. The presence of coastal ecosystems such as mangroves and coral reefs can dramatically reduce the damage caused by hurricanes or large waves.

Cultural Services: Cultural services are tightly bound to human values and behavior, as well as to human institutions and patterns of social, economic, and political organization. Thus perceptions of cultural services are more likely to differ among individuals and communities than, say, perceptions of the importance of food production. These are the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including:

- Cultural diversity. The diversity of ecosystems is one factor influencing the diversity of cultures.
- Spiritual and religious values. Many religions attach spiritual and religious values to ecosystems or their components.
- Knowledge systems (traditional and formal). Ecosystems influence the types of knowledge systems developed by different cultures.
- Educational values. Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.
- Inspiration. Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.
- Aesthetic values. Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, “scenic drives,” and the selection of housing locations.
- Social relations. Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies.
- Sense of place. Many people value the “sense of place” that is associated with recognized

features of their environment, including aspects of the ecosystem.

- Cultural heritage values. Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species.
- Recreation and ecotourism. People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

Supporting Services: Supporting services are those necessary for the production of all other ecosystem services. They differ from provisioning, regulating, and cultural services in that their impacts on people are either indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people. Some services, like erosion control, can be categorized as both a supporting and a regulating service, depending on the time scale and immediacy of their impact on people. For example, humans do not directly use soil formation services, although changes in this would indirectly affect people through the impact on the provisioning service of food production. Similarly, climate regulation is categorized as a regulating service since ecosystem changes can have an impact on local or global climate over time scales relevant to human decision-making (decades or centuries), whereas the production of oxygen gas (through photosynthesis) is categorized as a supporting service since any impacts on the concentration of oxygen in the atmosphere would only occur over an extremely long time. Some other examples of supporting services are primary production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat.

Figure 2.9. Ecosystem services and benefits obtained (MA, 2005)

Provisioning Services *Products obtained from ecosystems*	**Regulating Services** *Benefits obtained from regulation of ecosystem processeds*	**Cultural Services** *Nonmaterial benefits obtained from ecosystems*
• Food • Fresh water • Fuelwood • Fiber • Biochemicals • Genetic resources	• Climate regulation • Disease regulation • Water regulation • Water purification • Pollination	• Spiritual and religious • Recreation and ecotourism • Aesthetic • Inspirational • Educational • Sense of place • Cultural heritage

Supporting Services
Services necessary for the production of all other ecosystem serivices
• Soil formation • Nutrient cycling • Primary production

4. Key Issues for Conservation of Ecosystem Services and Biodiversity

In this section, the drivers of changes in ecosystem services and biodiversity loss and the potential role of economic valuation in addressing these drivers are discussed.

4.1. Threats to ecosystem services and biodiversity

Destruction of tropical rainforests through natural processes such as volcanism, fire, and climate change is well documented in the fossil record (Sahney *et al.*, 2010). These geological processes slowly alter the layout of the physical environment, increasing speciation and endemism (Sahney *et al.*, 2010). In contrast, destruction of tropical forests by human activity such as land conversion alters the environment on a much faster time scale. Forest loss and degradation are driven by a combination of economic, political, and institutional factors. The main direct drivers of tropical deforestation are agricultural expansion, high levels of wood extraction, and the extension of roads and other infrastructure into forested areas. Indirect drivers include increasing economic activity and associated market failures, a wide range of policy and institutional weaknesses and failures, the impacts of technological change, low public awareness of forest values, and human demographic factors such as population growth, density, and migration (MA, 2005).

The drivers of loss of biodiversity and changes in ecosystem services continue unabated. At a global scale, there are five indirect drivers of changes in biodiversity and ecosystem services: demographic, economic, sociopolitical, cultural and religious, and scientific and technological (MA, 2005). The drivers of degradation and loss of forests in India are also similar to those documented at the global scale. We discuss the threats to forest ecosystems in India in this section.

Forest conversion: Habitat destruction is identified as the main threat to biodiversity. Forests face threats on account of diversion of forest land for agriculture, industry, human settlements, and other developmental projects. From the beginning of civilization, with the advent of agriculture, increases in the agricultural area have come largely at the expense of forest lands. ISFR (2011) lists shifting cultivation as one of the major drivers of deforestation in some parts of India, particularly the northeast. The major threat to biodiversity and ecosystem services is loss of forest habitat. With growing population of India, the need for food, fibre, shelter, fuel and fodder along with need for economic development has increased leading to pressure on forest ecosystems. In addition to conserving the forests, it is necessary to restore the previously depleted habitats. Various floral and faunal species are threatened due to forest habitat degradation e.g. habitats of Great Indian Bustard in Madhya Pradesh, Gujarat and Rajasthan, and of the Lion-tailed Macaque in Western Ghats (NBAP, 2008). According to NBAP (2008), about one Mha of forest area has been diverted for implementing about 14,997 developmental projects since the enactment of the Forest Conservation Act in 1980. Shrinking or loss of grazing lands and village commons, which served as buffer between wildlife habitat and agriculture, have brought man into direct conflict with wild animals.

Extraction of timber and NTFPs: Degradation of forests results from illicit felling, excessive removal of forest products (fodder, fuelwood, timber), forest floor litter. As a result, some of the floristic and faunal components, including many keystone and endemic forest species are now left with a narrow eroding population which needs to be urgently conserved. The rich diversity of medicinal plants (over 6500 species) in India needs conservation and sustainable utilization, as their habitats are either degraded or the species are being overexploited. In fact, nearly 90% of the medicinal plants in trade are harvested from the wild. The medicinal plants constitute critical resource for health care of rural communities and for the growth of Indian herbal industry (NBAP, 2008). Fuelwood is the dominant source of cooking energy for rural population in India with forests contributing significantly to this. According to ISFR (2011), about 216 Mt of fuelwood is consumed in India of which about 27% is sourced from forests. Domestic demand for timber and fuelwood is well above the sustainable level.

Livestock grazing: Expansion of grazing lands to accommodate larger herds of cattle often requires conversion of forests to pasture, acting as a direct driver of deforestation. Prolonged heavy grazing contributes to the disappearance of palatable species and the subsequent dominance by other, less palatable, herbaceous plants or bushes. Excessive livestock grazing also causes soil compaction and erosion, decreased soil fertility and water infiltration, and a loss in organic matter content and water storage capacity (http://www.fao.org/docrep/x5303e/x5303e05.htm).

India has the largest livestock population in the world. The total livestock population in India is estimated to be 483 million during 2003. Though India accounts for only 2.4% of the world's geographic area but it accounts for about 15% of the global livestock population. The cattle (cows, bullocks and buffaloes) population density is nearly one per hectare. When sheep and goats are included in addition to cattle, the livestock population density further increases to 1.5 (Ravindranath *et al.*, 2008). In India, about 78% of forest area is affected by grazing (FSI, 1995).

Forest fire: The occurrence of forest fires can be attributed to natural factors (e.g. lightning, erupting volcanoes and droughts) and anthropogenic factors (e.g. fires lit for clearing land for shifting cultivation purpose and for initiating grass growth). The fires in Indian forests are mostly attributed to anthropogenic activities. The various reasons behind forest fires in India can range from the need for grass for grazing livestock, to facilitating the collection of fuelwood and certain non-timber products, to clearing the forests for shifting cultivation practices, grazing, etc. Livestock grazing alters forest dynamics by removing the biomass and intensive grazing sometimes leads to domination of a single or a few species, changing the species composition of natural vegetation, aggravating degradation of forests and making them fire-prone.

Further, during summer, when there is no rain for months, the forests become littered with dry leaves and twigs, making the forest floor prone to fires. The mountain ranges of Himalayas are the most vulnerable stretches of the world, susceptible to forest fires. Incidences of forest fires, especially in southern India, are also recurrent due to dominance of dry deciduous forests (Somashekhar *et al.* 2007). Forest fires are a major recurrent management problem in Western Ghats, even though the incidence and extent may vary from year to year, depending primarily on rainfall during the dry fire season.

Forest fires are of two types namely, surface/ground fire and crown fire. The most common type of fire in India is ground fire. The adverse impacts of forest fires in India (Bahuguna and Upadhyay 2002) include; i) loss of valuable timber resources, ii) loss of biodiversity and extinction of plants and animals due to habitat destruction, loss of natural regeneration and reduction in forest cover and biomass with ground fires, iii) severely affecting regeneration of plant and tree species, since the seeds on the forest floor get burnt out and young saplings die, iv) loss of carbon sink and emission of CO_2 and non-CO_2 greenhouse gases, v) soil erosion, vi) increase in population of weeds such as *Chromolaena* and *Lantana* which would have the capacity to regenerate better and flourish using the open areas created by burning of the native vegetation, vi) loss of livelihood for forest dependent communities in the long run. About 50% of the forest area in India is prone to forest fires.

Invasive alien species: Forest canopy opening and loss of tree cover and over grazing leads to invasion of alien weed species which are hardy and thus establish well. Among the major threats faced by native plant and animal species (and their habitats), the one posed by the invasive alien species is second only to that of habitat loss. The major plant forest invasive species include *Lantana camara*, *Eupatorium glandulosum*, *Parthenium* species, *Mimosa* species, *Eichornia crassipes*, *Mikania micrantha*, *Ulex europaeus*, *Prosopis juliflora*, *Cytisus scoparius*, *Euphorbia royleana*, etc. Lantana and carrot grass cause major economic losses in many parts of India. Highly invasive climbers like *Chromolaena* and *Mikania* species have over-run the native vegetation in northeast Himalayan region and the Western Ghats (NBAP, 2008). Trade and tourism have resulted in increment in invasive alien species by aiding their spread.

Anthropogenic climate change: Climate change has already had a significant impact on ecosystems according to various scientific reports. Climate change could become the major driver of changes in ecosystem services and biodiversity loss worldwide including causing changes in species distributions, population sizes, the timing of reproduction or migration events, and an increase in the frequency of pest and disease outbreaks by the end of the twenty first century in several countries (MA, 2005). Gopalakrishnan *et al.* (2011) conducted an assessment of the impact of projected climate change on forest ecosystems in India based on climate projections of the Regional Climate Model of the Hadley Centre and the global dynamic vegetation model IBIS for A1B scenario for the short-term (2021–2050) and long-term (2071–2100) periods. The assessment of climate impacts showed that at the national level, about 45% of the forested grids is projected to undergo change. This means the future climate is not optimal for the existing forest types and biodiversity leading to forest die-back and change in biodiversity in the long run.

Mining: Mining, particularly open cast mining, has significant impacts on forest and biodiversity of India. For example, coal is extracted through open cast and underground mining. In India, open cast mining accounts for nearly three-fourths of the total coal extracted in India. Forest degradation occurs on two counts, firstly, land has to be acquired for mining and secondly displaced families need to be rehabilitated and infrastructure need to be built for storing and transportation of coal. Mining has been undertaken in many states of India. For example, mining activities undertaken in Aravalli ranges - one of the oldest mountain ranges that extends from Delhi to Haryana, Rajasthan and Gujarat - has converted the ranges into a rocky wasteland, with soil erosion, reduced the recharging of ground water, and flooding the riverbeds with coarse sand, and degraded the forest area. Similarly, in the Western Ghats region, iron ore mining activity has resulted in degradation of land and forest area and impacted the water quality in the Bhadra River on account of siltation and contamination of water by the ore.

Forest fragmentation: The fragmentation of forests is a general consequence of logging of trees and forest land conversion for agriculture. Fragmentation decreases habitat simply through loss of land area, reducing the probability of maintaining effective reproductive units of plant and animal populations. When forests are cut down or burned, the resulting gaps may be too large to be filled in by the normal regeneration processes, permitting increase of rapid-growing, light-tolerant species, grasses and invasive species, thereby converting large gaps to scrub or grassland. Landscape fragmentation, which results in less connectivity of habitat to allow natural migration, limits the adaptive capacity of species and the viability of ecosystems (Vos *et al.* 2008). Further, fragments are much more easily accessible to human incursions than are intact forests.

4.2. Issues for conservation and restoration of forest ecosystems

In India, according to an assessment of forest conversion and loss made by Ravindranath *et al* (2012), based on district level analysis, about 63,650 ha was lost annually during the period 2003-05 and 99,850 ha annually during 2005-2007. Further, forests in India are also subjected to degradation due to non-sustainable extraction of fuelwood and NTFPs, over-grazing by livestock, forest fire, fragmentation and encroachment (Afreen *et al.*, 2011). All these drivers are likely to lead to loss of biodiversity and ecosystem services. Thus there is a need for concerted efforts to conserve forests which in turn will lead to conservation and restoration of biodiversity and ecosystem services. There are many efforts at national, state and local level to conserve, restore and sustainably manage the forests. The economic valuation of ecosystem services and biodiversity could assist in improving the ongoing conservation and restoration efforts. Some of the potential issues in conservation and restoration of forest biodiversity and ecosystem services are as follows.

1. **Periodic assessments and monitoring of status of biodiversity and ecosystem services and the threats and drivers of degradation and loss:** One of the critical issues in conservation and restoration is knowledge, information and data about the area under forests, tree crown cover, biodiversity status, carbon stocks and NTFP flows and other services from forests. Further, the factors driving or impacting the status of biodiversity and ecosystem services need to be identified and monitored periodically so that targeted policies and programmes could be launched to address these drivers. It may be necessary to identify policy, institutional and financial interventions as well as management practices which may impact the status of biodiversity and ecosystem services.

2. **Economic valuation of biodiversity and ecosystem services:** Absence of economic value of the biodiversity and ecosystem services could be potentially leading to ignoring their importance. As a result of this, these services are exploited. If their contribution to the economy is accounted for, government will be encouraged to invest more resources in their upkeep and maintenance. Potential high economic value of the biodiversity and ecosystem services may help in their conservation.
3. **Creating awareness about the economic value of biodiversity and ecosystem services:** Improved knowledge and information and its communication to stakeholders could assist in enhanced awareness leading to conservation of biodiversity and ecosystem services. Consumers may be discouraged from consuming forest products from non-sustainably managed forests or from threatened wildlife habitats.
4. **Cost benefit analysis:** Forest area and forest products have multiple uses and demands. Once valuation exercises have been carried out, a cost benefit analysis of conserved value of forest biodiversity and ecosystem services compared to alternate uses, often leading to degradation and loss, would assist in making decisions on conservation or restoration and in choice of appropriate use for forests.
5. **Technical and institutional capacity:** Conservation and restoration of biodiversity and ecosystem services would require strong technical and institutional capacity to generate information and data on their status, factors driving change or degradation, the economic value of the products and services, assessing effectiveness of the existing policies and ongoing programmes, enforcing tenure and benefit sharing mechanisms and monitoring.
6. **Integration of biodiversity and ecosystem services' concerns in planning:** Integration of information on the valuation of biodiversity and ecosystem services in planning and designing conservation and restoration policies and would enhance the effectiveness of conservation programmes.
7. **Effective policy formulation and implementation:** The first step in ensuring successful implementation of conservation and restoration programmes would entail formulation of appropriate policies to address the threats identified to biodiversity and ecosystem services involving of all the stakeholders and effective implementation and monitoring.
8. **Effective institutional arrangements:** Protection, management and utilization of forest resources requires strong local community institutions. Establishment of policies, rules, guidelines and legal provisions is necessary for community institutions to effectively participate in sustainable management of forests. There is a need for building capacity in the local community institutions for effective conservation and restoration of biodiversity and ecosystem services. Knowledge of total economic value of forest biodiversity and ecosystem services will enable and motivate community institutions conserve forests and demand appropriate price for any product extracted for commercial purposes.
9. **Development of sustainable forest management practices:** Local communities and economy will depend on the biodiversity and ecosystem services from the forests. The goal of conservation and restoration of biodiversity and ecosystem services should necessarily involve increased stake and flow of benefits to local communities. This would require effective protection, regeneration and sustainable harvesting. Thus there is a need for developing silviciltural, extraction and regeneration practices to ensure sustainable flow of products and services.
10. **International cooperation:** Conservation and management of biodiversity and ecosystem services requires international action since many of the products and services from forests are internationally traded. Very often, international market determines the rates of extraction or degradation of forests or wildlife. Thus international cooperation is required for formulation and effective implementation of conservation and sustainable management practices. Potential examples of international multilateral agreements which promote conservation and sustainable management of biodiversity and ecosystem services include; CITES, Convention on Biological Diversity, and United Nations Framework Convention on Climate Change.

5. Current State of Art on Valuation of Ecosystem Services and Biodiversity

5.1. Concept of valuation

Ecosystems have value because they maintain life on Earth and the services needed to satisfy human material and non-material needs (MA, 2005). In addition, people attribute ecological, socio-cultural, or intrinsic values to the existence of ecosystems and biodiversity. Ecosystems and the services they provide have economic value to human societies because people derive utility from their use, either directly or indirectly (known as use values). People also value ecosystem services they are not currently using (non-use values). Another set of values derived from ecosystems can be identified as the socio-cultural: people value elements in their environment based on different worldviews or conceptions of nature and society that are ethical, religious, cultural, and philosophical. These values are expressed through, for example, designation of sacred species or places, development of social rules concerning ecosystem use (for instance, "taboos"), and inspirational experiences. To some extent, this kind of value is captured in the concept of "cultural" ecosystem services.

The concept of total economic value (TEV) is a widely used framework for looking at the utilitarian value of ecosystems (Pearce and Warford 1993). This framework (Figure 2.10) typically disaggregates TEV into two categories: use values and non-use values.

Use value: refers to the value of ecosystem services that are used by humans for consumption or production purposes. It includes tangible and intangible services of ecosystems that are either currently used directly or indirectly or that have a potential to provide future use values. The TEV separates use values as follows:

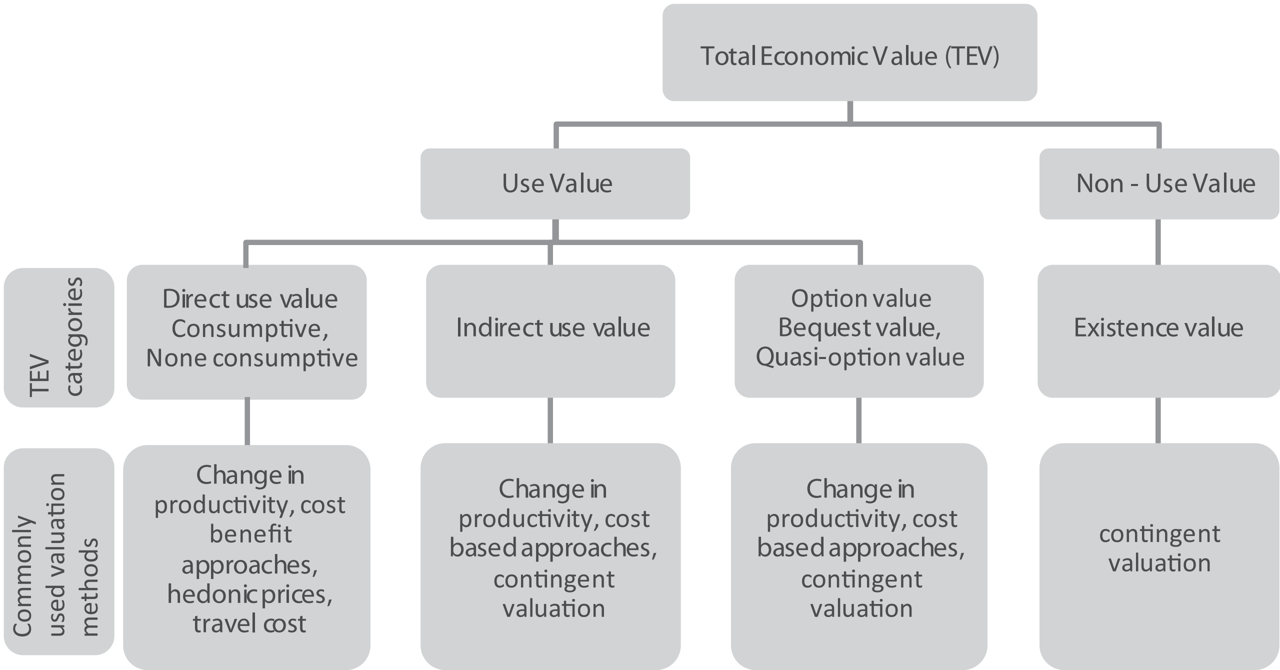
Direct use values: Some ecosystem services are directly used for consumptive (when the quantity of the good available for other users is reduced) or non-consumptive purposes (no reduction in available quantity). Harvesting of food products, timber for construction, medicinal products, and hunting of animals for consumption from natural or managed ecosystems are all examples of consumptive use. Non-consumptive uses of ecosystem services include enjoying recreational and cultural amenities such as wildlife and bird-watching, water sports, and spiritual and social utilities that do not require harvesting of products.

Indirect use values: A wide range of ecosystem services are used as intermediate inputs for production of final goods and services to humans such as water, soil nutrients, and pollination and biological control services for food production. Other ecosystem services contribute indirectly to the enjoyment of other final consumption amenities, such as water purification, waste assimilation, and other regulation services leading to clean air and water supplies and thus reduced health risks.

Option values: Despite the fact that people may not currently be deriving any utility from them, many ecosystem services still hold value for preserving the option to use such services in the future either by the individual (option value) or by others or heirs (bequest value). Quasi option value is a related kind of value: it represents the value of avoiding irreversible decisions until new information reveals whether certain ecosystem services have values that are currently unknown.

Non-use values: are also usually known as existence value (or, sometimes, conservation value or passive use value). Humans ascribe value to knowing that a resource exists, even if they never use that resource directly. This kind of value is the hardest, and the most controversial, to estimate.

Figure 2.10. Total Economic Value framework



A different source of the value of ecosystems has been articulated by natural scientists in reference to causal relationships between parts of a system—for example, the value of a particular tree species to control erosion or the value of one species to the survival of another species or of an entire ecosystem (Farber *et al.* 2002). At a global scale, different ecosystems and their species play different roles in the maintenance of essential life support processes (such as energy conversion, biogeochemical cycling, and evolution). The magnitude of this ecological value is expressed through indicators such as species diversity, rarity, ecosystem integrity (health), and resilience.

5.2. Valuation of biodiversity

While the number of studies based on the economic valuation of biodiversity and ecosystem services is growing worldwide, there is still a dearth of similar studies in India. This review intends to gather all of the relevant information from these studies to inform the current state of knowledge of the economic valuation of ecosystem services from Indian forests. The studies have been broadly categorized depending on the type of ecosystem service that have been valuated, namely provisioning, regulating, supporting and cultural services as per the Millennium Ecosystem Assessment classification (MA, 2005). Studies that have a more holistic approach in terms of multiple types of services have been classified separately.

5.2.1. Biodiversity related forest ecosystem services – Use value

These are the products obtained from ecosystems, including food, fiber and fuel (MA, 2005) and could be broadly termed the provisioning services. The valuation of provisioning services is generally straightforward where most studies quantify the resources extracted from forests and use market prices to determine the economic value.

Provisioning services

There are several studies conducted in different parts of India, particularly on the timber and non-timber forest products (NTFP) flow to the communities. In this section, a summary of some of the studies is presented.

Fuelwood, fodder and manure: In the Central Himalayan region, it is estimated that the cost of subsistence agriculture on the forest ecosystem is high (Negi and Semwal, 2010). This becomes evident because the local people in the Central Himalayan region traditionally utilize provisioning services of the forests to maintain agroecosystems, which also maintain high agrobiodiversity. Negi and Semwal (2010) compare the economic value of these provisioning services in two dominant forest types – oak and pine – in the Central Himalayan region of Uttarakhand, based on previous studies. To quantify various forest environmental services (e.g., fuelwood, fodder and manuring leaves), structured questionnaires were used in the two villages that were sampled, where one village was mostly dependent on a pine forest while the other was mostly dependent on oak.

In the oak dependent village, about 90% of the annual fuelwood consumption (177 t) and about 85% of the total fodder demand (1,045 t/year) came from the forests. A total of 19 ton manuring leaves were collected annually from forests in this village. In monetary terms, fuelwood worth Rs. 87,615, fodder worth Rs. 40,964 and manuring leaves of Rs. 10,450 were extracted from the forests each year in this village. In the pine dependent village, a total of about 120 ton fuelwood and 175 ton of fodder is consumed every year, of which only 25% and 23%, respectively are contributed by the forests. The annual monetary value of the fuelwood, fodder and bedding leaves extracted from the forests has been estimated to be Rs. 16,500, Rs. 22,138 and Rs. 6,050 respectively for the entire village. Thus the overall use value of forest resources is nearly three times less than in the oak-dependent village.

Joshi and Negi (2011) attempted to quantify and value the provisioning ecosystem services of forests in the western Himalayan region of Uttarakhand (Chamoli and Champawat districts). In this study also, the economic value was estimated for the two dominant forest types – oak and pine. The provisioning services (viz. fuelwood, livestock feed, NTFPs, wild edible fruits, minor timber, medicinal plants, etc.) derived from oak and pine forests by the local people were quantified and valued using a structured questionnaire. The monetary value of different goods was estimated on the basis of the prevailing cost paid in the local markets. The total value of the ecosystem goods collected from the oak forests was estimated at Rs. 2,164,247/ village/year, which computes to Rs. 5,676/person/year. Similarly, the total value of the ecosystem goods collected from the pine forests was estimated at Rs. 1,589,642/ village/year, which computes to Rs. 4,640/person/ year. Thus, oak forests were found to be more economically profitable in terms of provisioning services, which is in line with other such studies (Negi and Semwal, 2010). This study serves to highlight the different economic values of ecosystem services between different forest types, when viewed from ecological and social considerations.

Timber, fuelwood and NTFPs: One of the monographs published as part of the Green Accounting for Indian States Project (Gundimeda *et al.*, 2005) modeled the incorporation of forest resources into the national accounts of India's states and union territories, using the satellite SEEA framework. In terms of provisioning services, only timber, fuelwood, and NTFPs were considered. According to the monograph, if timber and fuelwood are the only products obtained from forests then the asset value of timber production of forest equals the discounted sum of total net rent of timber and fuelwood. As the forests are also a source of NTFPs, the asset value should also include the discounted value per hectare of these products. This implies that the asset value depends on the discount rate, age of the forest, etc. The economic accounts of NTFPs are derived by multiplying the area accounts with the present value per hectare of the products. Further, when forests are logged for timber and fuelwood, the NTFPs generated from the forests are lost forever. Hence, the area subjected to logging is multiplied by the value of the NTFPs lost. Their results show that there is a net loss of Rs. 22,766 million in value of the NTFPs obtained from forests, for all states together, due to logging of forests for timber and fuelwood and transfer to non-forest purposes; whereas the total closing value of timber and fuelwood for different states was Rs. 11,982,912 million, with all of the assumptions in place. For e.g., it was assumed that the value of NTFPs is taken to be 10 times the value recorded by the State Forest Department.

Timber and NTFPs: Mahapatra and Tewari (2005) carried out a detailed accounting of commercially valuable forest products harvested from dry deciduous forests of Eastern India to highlight the economic worth of forests and contribution of NTFPs. The study was carried out in two districts, coastal Dhenkanal and inland Keonjhar. The value of one hectare of forest was estimated based on returns from NTFPs and timber, where annual harvest levels, market prices and extraction costs were measured through yield assessment as well as household and market surveys for NTFPs, while timber yield was derived from secondary data. After deducting the costs associated with the harvesting and sale, the net revenue from all NTFPs from one ha of dry deciduous forests annually was Rs. 4,523±54 for the coastal area and Rs. 6,088±67 in the inland area. Considering 25% of the products (fruits, seed) is left in the forest for regeneration, the NPV of non-wood products was estimated to be Rs. 36,584/ha and Rs. 48,535/ha for the coastal and inland areas, respectively.

The dry deciduous forests of the region could produce 67 m^3/ha of merchantable timber. If harvested in one felling, round timbers were estimated to generate net revenue of Rs. 552,475/ha, at the stump site, at prevailing round log prices. Felling of this intensity would, however, reduce the net revenue to zero for the year after felling and during the succeeding years until mature trees reappear. The forest management plan prescribed logging on a selection basis under a rotation regime of 40 years cutting cycle. After deducting the harvest and transport costs, net revenue of Rs. 375,000/ha was estimated for each cutting cycle. Discounting a perpetual series of the periodic revenues back to its present value a net worth of Rs. 12,063/ha was obtained. This result shows that NTFP extraction has a competitive advantage over timber logging. Considering the fact that sustainable timber and non-timber production is possible if rotational felling is adopted, one hectare of dry deciduous forest is estimated to have a net present value of Rs. 54,622/ha.

Fuelwood and NTFPs: Sarmah and Arunachalam (2011) estimated the contribution of NTFPs to household economy of the people of Changlang district of Arunachal Pradesh. They conducted detailed household surveys using a semi-structured questionnaire to gather information on the NTFP plant species and its utilization. Secondary data was collected from the forest department as well as from the civil administration. The monetary value was calculated by multiplying the quantity consumed with the average market price of that particular product prevailing at nearest local market. Market surveys were conducted by periodic visits to the local markets in all selected sites.

Fuelwood consumption was estimated separately in two different seasons viz. winter (October to March) and summer (April to September). The monetary value of consumed fuelwood that contributed to the household income was estimated a minimum of Rs. 2,758/household/year and a maximum of Rs. 5,892/household/year. The monetary values of house building materials like bamboos, canes, and thatching materials (leaves of *Zalacca secunda* and *Livistona jenkinsiana*) were also estimated. Bamboo was seen to provide income in the range of Rs. 1,620 to Rs. 2,346/household/year. Among the thatching materials, leaves of *Zalacca secunda* contributed about Rs. 239 to Rs. 1,214/household/year, and leaves of *Livistona jenkinsiana* contributed a maximum of Rs. 768/household/year. Canes contributed a minimum of Rs. 664 and a maximum of Rs. 1,251/household/year. The annual monetary values of wild edible NTFPs in local markets was estimated to range between Rs. 3,103 to Rs. 13,460 for bamboo shoots, Rs. 6,616 to Rs. 32,931 for wild leafy vegetables, Rs. 5,425 to Rs. 38,868 for wild edible mushrooms, Rs. 2,788 to Rs. 7,829 for cane shoots, and Rs. 2,700 to Rs. 43,700 for bushmeat.

Appasamy (1993) conducted a case study in Kadavakurichi Reserve Forest in the foothills of the Palani Hills, an offshoot of the Western Ghats in Tamil Nadu. The study aimed at carrying out an economic valuation of NTFPs. Surveys were used to gather information on quantities of NTFPs collected and local market prices were applied to derive economic values. For this purpose, the Palani Hills Conservation Council (PHCC) developed an innovative methodology called the footpath survey, where they identified 43 entry paths into the Reserve Forest originating from ten of the villages. Local educated youths were employed to conduct the survey. All the footpaths were simultaneously monitored from dawn to dusk one day each week for 7 weeks and information about the activities of those who entered and left the forest were noted. The total value of fuelwood collected annually (allowing for the rainy season) from Kadavakurichi Forest was estimated to be in the order of Rs. 2,50,000. With regard to fodder, local villagers graze their livestock in the forest throughout the year, but outsiders bring their livestock for about 5 months during the post-agricultural season. The daily intake of fodder by the local and non-local animals was estimated to be 11,725 kg daily while for those from outside 13,970 kg. At Rs.0.25 per kg, the opportunity cost of the fodder consumed by the livestock was estimated to be around Rs.1.6 million per year. The value of honey collected was also estimated and based on a collection rate of approximately ten liters per day, the annual total value of honey collected over a five month period was estimated to be around Rs.37,500. Medicinal plants, small game, green manure, and other goods were also collected, but their contribution is relatively small. In summary, the value of fuelwood, fodder and honey collected annually from Kadavakurichi Reserve Forest was estimated to be about Rs. 1.9 million. Since the forest covers an area of about 900 hectares, the value of NTFP collected and used is about Rs. 2,090 per hectare per year.

NTFPs: Narendran *et al.* (2001) economically valuated the non-timber forest product (NTFP) collection in the Nilgiri Biosphere Reserve (NBR), in southern India. For this study, the plant diversity was first estimated, which was followed by a survey carried out in two phases. During the first phase a questionnaire survey was conducted to assess the socioeconomic status of the households. In the second phase, a detailed survey on the extraction of NTFPs was done, which provided information on the percentage of people involved in NTFP collection, the different NTFPs extracted, the time spent on gathering these products, the quantities extracted as well as the quantities consumed at home and those that were marketed. Estimates of the quantities and value of NTFPs extracted per hectare and at forest zone level were made. The per capita values obtained from the sample household surveys were extrapolated to the rural population in each forest zone considering the total number of rural households. Further, the total quantity of NTFPs extracted and financial values estimated for each forest zone were divided by the total area under the respective forest types to obtain per hectare values. The mean annual per capita household income from NTFPs ranges between Rs. 134 to Rs. 4,955. The tropical moist deciduous zone has the highest per hectare extracted income of Rs. 3,780/ha/year and the tropical dry thorn has the least of Rs. 92/ha/year. The mean annual extractive value of one hectare of the reserve forest from NTFPs is estimated to be Rs. 1,211.

Murthy *et al.* (2005) undertook a study to evaluate the flow of non-timber forest products (NTFPs) in the four forest types of Uttara Kannada district of the Western Ghats region. A questionnaire survey was conducted to collect information on diversity of NTFPs extracted, the parts used, end use, as well as quantity of NTFPs gathered per typical trip and quantity collected in a season. Secondary data regarding the extraction of several NTFPs from different forest divisions in the district was collected from the Forest Department records. The financial value of the quantities of NTFPs gathered were computed by considering the total population in each of the forest zones and the per household values computed after excluding fuelwood, grass for fodder, green and dry leaves for manure and fencing poles. The estimated financial value realized per household was Rs. 3,445 in the evergreen zone and Rs. 3,080 in the moist deciduous zone, while in the semi evergreen and dry deciduous zones, an income of Rs. 1,438 and Rs. 1,233 were realized, respectively. Similarly, the financial value realized per hectare was estimated by the study and it ranges from Rs.634 in the dry deciduous zone to Rs. 1,801 in the evergreen zone, with a mean of Rs. 1,159/ha/year.

Medicinal plants: There are about 1,500 to 2,000 species with known medicinal worth in India which support an estimated 5,000 indigenous drug manufactures, which make about 2,000 preparations in different parts of the country. 80% of the raw material requirement for these manufacturers is met from the forests. According to the Ministry for Environment and Forests (MoEF), market value of allopathic medicines alone derived from plants was over US$ 43 billion annually and there is still vast untapped potential for developing drugs from wild plants occurring in tropical forests. Purushothaman *et al.* (2000) in their paper on the economic valuation of extractive conservation derive the lost pharmaceutical value in the tropical deciduous forest near Jabalpur, Madhya Pradesh, where establishment of a multipurpose hydroelectric project (Rani Avanti Bai Sagar Pariyojana) across the river Narmada at Bargi, submerged nearly 8,500 ha of such forestland. Total pharmaceutical value of the forest is supposed to be reflected by the total worth of herbal raw material calculated from the sustainably harvestable raw material from each of the species and their market prices. Five plant species of high economic importance were identified from a sample survey of retail medical outlets. To make this estimate of medicinal worth realistic, different kinds of plants, plant parts (herbs, climbers and trees yielding fruits, leaves, barks and tubers etc.), different therapeutic properties (tonic, anti hemorrhage, cardio-protective and anti diabetic) were chosen from those plants widely used in drug manufacture in India, especially by those firms located near the study area. The total annual medicinal worth of the lost forests (mean annual benefit per species x number of medicinal plant species) was estimated to be US$ 18.02 billion and US$ 27.36 billion at a discount rate of 5% and 10% respectively.

The National Medicinal Plants Board, Department of AYUSH, Government of India, has carried out a nation-wide study to assess the demand and supply of medicinal plants in India. Ved and Goraya (2007) have presented the basis and results of this study. A list of 960 medicinal plants that are source of 1289 botanical raw drugs have been listed from literature available and data collected during the study on consumption of plant species by manufacturing units and raw drugs that are traded. The annual demand of raw drugs in country has been estimated to be 3,19,500 tonnes for data collected in year 2004-2005. 1,223 rural households in 5 states were also sampled to estimate demand of medicinal plant resources for non-commercial uses by rural households. Results indicate that 'Amla' is the highest consumed botanical drug and about 70% of total export comes from Henna, Isabgol, Senna and Myrobalans. Total trade value for 3,19,500 tonnes of drugs comes out to be Rs. 10,690 million annually. Annual turnover of herbal hennah industry was estimated to be Rs. 88,000 million.

Infrastructure: Biological resources provide a wide range of industrial materials which include building materials, fibers, dyes, resins, rubber and oil. In addition, healthy economic system has been provided by the biodiversity and the ecosystem goods (Gautam et.al. 2010).

Cultural services - Tourism / Recreation

Cultural services are the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including inspiration, ecotourism and cultural heritage values (MA, 2005).

Badola *et al.* (2010) assessed the recreational value of the Corbett Tiger Reserve (CTR), located at the foothills of the Central Himalayas in Uttarakhand. The vegetation of the area is a mosaic of predominantly dry and moist deciduous forest as well as scrub savannah and alluvial grassland. The individual approach to travel cost method (TCM) was used to estimate the recreational value. Tourists were interviewed regarding their cost of travel, distance traveled, time taken to reach the destination, reason for travel, and number of visits in a year. The total cost of travel was calculated for each tourist by adding the travel cost and the monetary value of the time spent in travel to get to CTR. The travel cost was the round-trip cost by the mode of transportation used, while the cost of time spent was estimated from the average wage per hour and the time spent on the round trip. With the cost per visitor being US$2.5, the consumer surplus worked out to be US$1,67,619/year, which was the economic estimate of the recreational services of CTR.

Hadker *et al.* (1997) surveyed the residents of Mumbai and elicited their willingness to pay for the maintenance and preservation of Borivli National Park (BNP) using contingent valuation method (CVM). The authors conducted face-to-face interviews as opposed to mail or telephonic interviews. The study elicited willingness-to-pay (WTP) as opposed to willingness-to-accept compensation for loss. High response rates were attained. A conservative design was selected. Low bid levels were used and every question was placed in context of the household's budget constraint, reminding respondents of the alternative and varied uses of their money. Having statistically adjusted for embedding and anchoring effects, households were willing to pay exclusively for BNP, on average, Rs. 7.50 per month, for the next five years. In order to avoid sample bias while extrapolating from the sample to Mumbai city, they referred to a government study on economic and demographic aspects of Bombay's population and found that household characteristics (income, family size, mean age) were very close to the sample from their study. Extrapolating to Mumbai, using a population size of 10 million with a family size of about 4.5, they obtained WTP of Rs. 20,685,000 per month for the maintenance and preservation of BNP. This amounts to an annual value of Rs. 248 million. As the payment was to be made over a period of five years, the total net present value of annual amount was estimated to be equal to Rs. 1,033 million.

5.2.2. Forest regulating services

These are the benefits obtained from the regulation of ecosystem processes, including climate regulation and air quality maintenance (MA, 2005).

Provisioning ecosystem services of oak and pine forests: Joshi and Negi (2011) in addition to quantifying and valuating the provisioning ecosystem services of oak and pine forests in the western Himalayan region of Uttarakhand, also studied stakeholder perceptions of the regulating services of the forests. Approximately 220 people were selected randomly from the villages of the region, and two consultation meetings were held separately in which the participants were asked to independently list different ecosystem services provided by the oak and pine forests. The participants were told to assign perceived value on a scale of 0 to 10 (0 being the minimum and 10 being the maximum), for the ecosystem services provided by the two forest types separately. The participants listed seven regulating services, including purification of air and water, prevention of extreme events like landslides, prevention of soil erosion, soil moisture retention, soil fertility maintenance, and climate regulation by rainfall interception. Interestingly, all these services scored a higher perceived value for oak forests compared to pine forests. Moreover, these services did not have a direct sale value in conventional markets but had direct relevance (high indirect use value) to the rural people for their existence, which was amply reflected in the marks assigned by the stakeholders to these services.

Soil erosion and water recharge and flood control: Kumar *et al.* (2006) account for and monetize prevention of soil erosion, augmentation of groundwater as well as flood control functions and benefits of Indian forests for 2002/03. The total value of these three ecological services rendered was estimated at Rs. 2,40,742 million in 2001, with an annuity value of Rs. 60,18,559 million and Rs. 2,25,503 million in 2003, with an annuity value of Rs. 56,37,596 million.

i) Prevention of soil erosion: A four-year study on the effect of forest vegetation in preventing soil erosion in the hills of Bheta Gad, Uttaranchal, estimated that the soil loss prevented by the broad-leaved forest was approximately 12.295 t/ha/year (Kumar et.al. 2006). This rate of prevented erosion was adopted in the study for estimation of erosion benefits in India. For the given dense forest area of different states of India in 2001, soil loss was estimated by multiplying the differential soil loss prevented by the presence of forest to existing forest areas (in ha). The soil loss prevented by Indian forests was estimated to be 5,14,685 million kg and 4,82,196 million kg in 2001 and 2003, respectively. To value the soil loss, they used an approach known as the resource value of soil loss, where soil is considered as the supplier of vital nutrients and artificial fertilizers are used as a marketed proxy for valuation of nutrients lost due to erosion. It is based on the cumulative depletion of soil nutrient content due to erosion. The estimations of economic value of nutrient loss in 2001-2002 was Rs. 50,244 million and in 2003 it was Rs. 47,072 million.

ii) Augmentation of groundwater: In India, rainfall is the most important source of groundwater recharge. In the absence of adequate vegetative growth, most of the rainfall is lost as run-off and surface flows. In this study, run-off coefficient and total run-off was derived from numerous studies under various soil types cover and vegetative area, to arrive at a broad conclusion on run-off rate in different forest types of India. The two main assumptions were that rainfall occurs at uniform intensity over the entire watershed (forest) area and that run-off rate is the same for the entire forest area. Water/hydrological balance methods were used to calculate the additional recharge facilitated by the forest, where it was assumed that the precipitation quantum left over after evapo-transpiration, surface run-off and saturation of soil is available for groundwater recharge. The price of water varies across states and uses and the estimation of Indian forests' water recharge function was at an opportunity cost of Rs. 4.5 per m^3, excluding any distribution or environmental costs. The economic value of differential water recharge was estimated to be Rs. 1,325 million and Rs. 1,238 million in 2001 and 2003, respectively.

iii) Flood control: The link between deforestation and floods has been found to be very significant. While the overall impact of forests on flood management depends upon various factors, including type of forest, intensity and duration of rainfall, and general topography of the area, forest area is a critical determinant of flood intensity and frequency. The flood avoidance benefits were estimated by calculating the total flood damage in four categories, namely human lives lost, heads of cattle lost, damage to crops and houses, and damage to public utilities. The flood avoidance benefits were estimated to be Rs. 1,18,510 million and Rs. 1,11,030 million in 2001 and 2003, respectively, at 35% of the total damage, as entire flood damage can never be mitigated by forestry alone.

Valuation of forest soil: Kiran & Kaur (2011) worked on the economic valuation of forest soils of Halol Range, Gujarat, using a cost-benefit analysis approach. Their focus was on the economic loss or benefit as a result of change in soil nutrient status (soil fertility). They performed a multi-temporal analysis of the soils with respect to changes in the soil fertility status from 1997-2009, and these changes were economically valuated using the nutrient replacement cost technique. Economic valuation of a single nutrient showed that there was economic loss of Rs. 948/ha in case of Nitrogen and economic benefit of Rs. 2,123/ha and Rs. 5,112/ha in case of Phosphorus and Potassium respectively (during a period of 12 years). The overall economic benefit was Rs. 388/ha in 2009, in comparison to the loss of Rs. 5,899/ha in 1997.

Carbon sequestration: Singh (2007) estimated forest carbon pool in Indian Himalayas to be about 5.4 billion tonnes (biomass+soil), which is about equal to the annual carbon emission from fossil fuels in Asia. This carbon value was compiled from various sources, particularly those generated by ecologists of Kumaun University, Nainital. In relatively undisturbed forests of various ecosystem types in Uttarakhand, the amount of carbon accumulated in total forest biomass in the state was estimated to be 6.61 million tonnes (Mt) annually, valuing Rs. 3.82 billion at the rate of US$ 13/tonne of carbon. The forested area taken into consideration was based on remote sensed data in which biomass and productivity were determined by actually harvesting trees and carbon by measuring concentration in each component. Their estimates based on six undisturbed forest stands of all major types along an attitudinal gradient of over 2,000 m were adjusted for disturbed conditions in the region by multiplying with a correction factor of 0.63. For soil, the depth was extended from 30 cm to 150 cm (derived from other studies).

Lal and Singh (2000) estimated the carbon sequestration potential of Indian forests and their findings suggest that, even with modest efforts towards afforestation, Indian forests will continue to act as a net carbon sink in future. They obtained the total carbon pool of Indian forests in 1995 by estimating the total biomass of Indian forests from the volume of growing stock recorded in 1995, which was then converted into carbon content by multiplying it with a factor of 0.45 (as prescribed in the IPCC 1995 guidelines). Then, the annual carbon flux from these forests for the years 1985, 1990 and 1995 was computed by using the annual forest productivity and annual extraction of food from forests, which are reported at regular intervals, and the area occupied by various forest types in India, which has been assessed periodically since 1983. They also take into account the annual national mean above-ground biomass productivity of forestry plantations to obtain total biomass increment for Indian forests. The forestry plantations under the national afforestation programme have significantly higher productivity compared to natural forests, and they have, therefore, included a fraction (1/4) of afforested area in their computations for estimating the annual carbon flux. However, factors such as shifting cultivation, natural decay of wood and carbon release from soil were not considered in this study. Total annual carbon uptake increment was estimated to be 27.8 Mt, 32.1Mt and 34.1 Mt for the years 1985, 1990 and 1995 respectively, suggesting that the forestry sector and plantations had the potential to remove about 0.125 billion ton of CO_2 from the atmosphere in the year 1995. However, after subtracting the annual carbon loss (released back to atmosphere) of 22.23 Mt due to reported extraction from forests from total annual carbon uptake increment, the net annual carbon uptake was estimated to be 5.64 Mt, 9.90 Mt and 11.88 Mt for the years 1985, 1990 and 1995, respectively.

Lal and Singh (2000) went further to estimate the net carbon flux through forestry in 2020 and 2045 based on the present state of Indian forests and an assumed scenario for afforestation rates, productivity and area available. The net annual carbon uptake was estimated to be 11.02Mt and

6.79Mt for the years 2020 and 2045, respectively. Thus, the carbon sequestration potential of Indian forests were estimated to be 4.1 and 9.8 Gt of CO_2 by the years 2020 and 2045 (cumulative CO_2 uptake from the atmosphere).

Dwivedi *et al.* (2009) attempted to assess the amount of carbon sequestered by the Kerwa Forest Area (KFA), a southern tropical dry deciduous scrub forest, located about 10 km from Bhopal in Madhya Pradesh. To do this, they first estimated the biomass of trees in the sample plots, multiplied it by the carbon value of the species for estimating the net carbon present in the total aboveground biomass, and this aggregated carbon value was then extrapolated for estimating the total aboveground carbon stock present in the KFA. The carbon stock was estimated to be 6,602 kg for the trees present on the sample plots. After extrapolation, they found that about 19,417 tonnes of carbon was present in trees of the KFA with an average density of 1,254 tonne/km^2.

Badola *et al.* (2010) derived the carbon sequestration value of the forests of the Corbett Tiger Reserve (CTR) in Uttarakhand, by using replacement cost method. This additional aboveground carbon stored in the forests of CTR on an annual basis was estimated to be 3.84 Mt, after deducting biomass extracted for fuel and fodder by local communities. Monetary value was converted into annual flows by discounting it at a market interest rate of 10%. They used the average costs (US$/tonne) of CO_2 mitigation as per the then existing market price of certified emission reductions (CER) from registered projects in India. Prices for CERs from registered projects were quoted between US $17–21 during 2008. The total cost of CO_2 mitigation by the forests of the reserve was estimated as US $63.6 million, with annual flow of US $65/ha/ year.

In a study on the carbon sequestration potential of Indian forests, Kadekodi and Ravindranath (1997) found that when the net annual carbon emission in forest ecosystems is considered (uptake-release), the carbon emission from India was offset by a net sequestration of 5 Mt in forests under succession and in tree plantations. The potential for carbon sequestration through forestry in India has been estimated and shown to be significant enough to offset 25–50% of national carbon emissions. The authors also derived an economic value for existing forests, with an area of 64 Mha, including use and option values. This worked out to be a total of Rs. 12,314 billion. The use value was defined for timber plus non-timber only, with an average use value at all India level to be Rs. 96,203/ha.

Forests and watershed services: There are many studies where the ecosystem services related to the watershed role of forests are considered. According to Lele (2009), studies on economic valuation of watershed services of tropical forests are characterized by conceptual errors, over simplified biophysical models, lack of social and technological context, and focus on lumpsum numbers. Greater integration of concepts, methods and latest results, and attention to context-specificity for generating policy-relevant insights are suggested. Forested ecosystems are said to provide a range of watershed services, including hydrological regulation in the form of low-flow augmentation, flood control and groundwater recharge, water quality enhancement, and soil conservation. However, the 'watershed service value' of a particular forest or land-cover type is meaningfully defined only in terms of the changes in human well-being downstream resulting from its replacement by an alternative land use. It also follows that the value of in situ soil fertility of forests cannot be considered a service to agriculture or measured in terms of agricultural productivity or replacement cost, because forest soils (by definition) do not generate agricultural produce. Lele (2009) suggests generation of aggregate economic welfare instead of single monetary values to understand their distribution and different ways of aggregation. Further, location-specific and realistic analyses of what institutional, cultural and political factors determine the impacts, and how ecosystem users respond to these impacts, both downstream and upstream, may be required for environmental policy-making.

5.3. Holistic studies

Chopra (1993) estimated the value of non-timber goods and services from tropical deciduous forests in India, where tropical moist deciduous forests and tropical dry deciduous forests together comprise 66.5% of the total forest area. Non-timber forest products in this study include fuelwood, fodder, medicinal herbs, fruits, game, and intermediate use goods (e.g., dyes, gum, latex) which have been referred to as “minor forest products” in India; the assumption being that timber is the major product. Use, option and existence values of these non-timber goods and services are estimated, where the use and option values constitute an approximation of the value of the resource for the national economy. The present and future value of services accruing to the national economy is also estimated. The existence value, on the other hand, measures value of forests to the global economy in terms of preservation of sustainable ecosystems, carbon sinks and preservers of biodiversity. A mix of market and non-market approaches has been used in the imputation of value. Wherever a good is marketed, as is the case of fuelwood, fodder and other minor forest products, its exchange value, approximated by market price, have been used as a measure of economic value.

The total value of goods such as fuelwood, fodder, and forest products varies from a minimum of US$ 888/ha to a maximum of US$1,086/ha, while that of services like soil conservation, nutrient recycling, and tourism/recreation varies from US$932/ha to US$1,920/ha. The total present value of NTFPs and services available from a tropical deciduous forest in India varies from a minimum of US$4,034 to a maximum of US$6,662 per hectare, if use, option and existence value are all taken into account. According to Bawa and Godoy (1993), these estimated values are comparable to economic returns that might be obtained from converting forests to other types of land use, even though Chopra does not include values for losses in carbon, water balance and evapo-transpiration that inevitably result from deforestation.

The Natural Resource Accounting for Goa project (Parikh *et al.*, 2008) aimed to construct asset and flow accounts for the forest assets of Goa based on the framework provided by Verma (2005) and Gundimeda *et al.*, (2005). The study attempted to estimate various use values of forests of Goa using various methods like the market price, substitution approach, productivity method, welfare method, avoidance cost and benefits transfer approach. For certain values it also used findings of specific valuation studies undertaken in India and other countries with similar forest types to extrapolate for the entire state. Further the study treats total growing stock in forest as stock value and all other values as flow values and calculates them on annual basis. After taking into account the values of timber, fuelwood, fodder, ecotourism, watershed benefits, carbon sink, biodiversity, the total economic value of Goa forest was estimated to be Rs.44,300 million for the total forest area of 2,156 km^2, but this includes ambiguous values, such as eco-tourism in Goa, which is not only due to forests but also due to several factors like beaches and historical monuments.

Singh (2007) made the first approximations of values of Himalayan forest ecosystem services, primarily based on the estimates of Costanza *et al.* (1997) for temperate and tropical forests. Singh used midpoints of the values estimated for tropical forests (US$ 2007/ha/yr) and temperate/boreal forests (US$ 302/ ha/yr) because the Himalayan forests are closer to temperate forests in terms of species richness, but in terms of ecosystem functioning they are closer to tropical forests (Zobel and Singh, 1997), the latter factor being more important in relation to ecosystem services. The total value of forest ecosystem services flowing from Uttarakhand is about US$ 2.4 billion/ year and at Indian Himalayan level it is Rs. 943 billion/ year. This includes climatic regulation, disturbance regulation, water regulation and water supply, soil formation, erosion control, nutrient cycling, water treatment, biological control, food production, raw material, genetic resource, recreation and cultural values.

Himachal Pradesh, a hill state serving as a major watershed to numerous rivers as well as rural and urban areas, has 66% geographical area under forests. It plays a pivotal role in the regional and global economy. Verma (2000) generated the economic value of various goods and services provided by the forests of Himachal Pradesh. She took into account values that accrued to various stakeholders and sectors in the form of direct consumptive benefits like timber, fodder, fuelwood, NTFPs; direct non-consumptive benefits like ecotourism and recreational; and indirect benefits like watershed functions, carbon sinks, micro-climate, biodiversity and employment. The study accounted for the physical wealth of Himachal forests; used appropriate valuation techniques drawing information from other studies conducted in forest valuation in India and similar countries to provide an extensive estimate of economic value of Himachal forests. It is based on readily available data and no primary survey was conducted for ground truthing of the economic values so generated.

The actual forest cover in Himachal covering an area of 14,346 km^2 generated an economic value to the tune of Rs. 0.745 million/hectare and if the entire area under legal forests is used as denominator, the value reduces to Rs. 0.289 million/hectare. The maximum per hectare value is generated by watershed function followed by carbon sink, biodiversity, ecotourism, all of which are non-marketed values.

Chopra (1998) has given various alternative methods to evaluate biodiversity. She has evaluated use value of protected area in India taking Keoladeo National Park (KNP), Bharatpur as study site. KNP has been designated as a Ramsar site and is a home for migratory birds. It has a variety of habitats such as wetland, grassland and semi arid forested grassland. The park has been used by the scientist community for the purpose of research and analysis which is a kind of use value. Travel cost method (TCM) was used to determine the value of tourism for KNP and it is used as a measure for price of site. Data regarding tourists' travel, stay expenses, duration of stay and various socio-economic characteristics was collected. Tourists were also asked for their willingness to pay (WTP) for conservation of park. Semi log demand functions were set up for tourism which indicates that travel cost is a proxy variable for price in determining demand for tourism services. But it is considered more appropriate to estimate consumer surplus using local cost method which come out to be Rs. 427 per visit for Indians to Rs. 432 per visit for foreigners. Other than TCM, multi-criteria analysis was also carried out to draw out values places by stakeholders on KNP. They were asked to rank various aspects of park such as ecological functions, consumption of goods, aesthetic, ritual and cultural values, livelihood, existence of rare species etc. Responses from villagers have shown that they have kept value obtained from livelihood provided and services obtained from on top with highest scores followed by ecological functions, while that from visitors or non users have given aesthetic value the highest scores.

A scoping study from Uttarakhand (Verma *et al.*, 2007), a state rich in endemic biodiversity and forests that provide wide varieties of ecosystem services like regulated water supply, nutrients rich soil, evaluates the value of forest ecosystem services of the Uttarakhand Himalayas in the current GDP (Gross Domestic Product). The framework for the study to evaluate the ecosystem services of forests of Uttarakhand was based on the estimates of the project on Natural Resource Accounting (NRA) of land and forest for the states of Madhya Pradesh and Himachal Pradesh. Studies under this project were carried out by IIFM for Central Statistical Organization, MOSPI, GOI (2003-06). The economic value of watershed services computed from the forest of Uttarakhand is around Rs. 1,247,610 million followed by Rs. 173,120 million and total indirect benefits worth Rs. 173,120 million. The same study was carried out for Himachal Pradesh also. The total economic values of various ecosystem services under the same scenario of IIFM-CSO (2005) were Rs. 646,753 per ha for the forest and tree cover in Himachal Pradesh. The ecosystem services include direct consumptive values - timber logging, fuel wood, fodder, grazing, minor forest produce, direct non-consumptive value – ecotourism, including Indian as well as foreign visitors and indirect benefits – watershed services, microclimatic factors, carbon stock and carbon flux, biodiversity and employment generation.

The total carbon sequestration value of forests of Uttarakhand was estimated to be US$ 85.93 million in which five different types of forests were taken into account - Temperate Conifer Forest, Temperate broad Leaved, Tropical Coniferous (Pine), Dry Deciduous and Sub Tropical (Sal) forest. The total Annual Economic Values of 17 Ecosystem Services of the Forests of Uttarakhand based on estimates of Costanza et. al. (1997) Framework was 1,150 US$ /ha /yr. Different ecosystem services which were identified: climate regulation, distribution regulation, water regulation and water supply, erosion control, soil formation, nutrient cycling, waste treatment, biological control, food production, raw material, genetic resource, recreation and cultural services. As part of the same paper, an independent study conducted by LEAD India and CHEA for the valuation of ecosystem services of forests of Uttarakhand has been quoted. The annual silt control value extrapolating to the forest and tree cover area of Uttarakhand was Rs. 2,062 million. Total annual Carbon sequestration value for the FTC (Forest Tree Cover) area was Rs. 118,610 million. For soil carbon pool annual value was Rs. 118,610 million. Annual recreational value of Uttarakhand both from Indian and Foreign tourists in the year 2005-06 was Rs. 124 million. It was found that the total revenue generated annually from logging, fuelwood, fodder and other products about Rs. 15,106 million. The monetary value of Oak and Pine forest was estimated in Mountain villages of Uttarakhand. The study reported that the annual fuelwood consumption from Oak and Pine forests is 117 ton and 120 ton which is equivalent to Rs. 87,615 and Rs. 16,500 per year respectively. Total annual fodder extraction was computed as 104 ton and 175 ton per year which costs Rs. 40,964 and Rs. 22,138 from Oak and Pine forest of Uttarakhand respectively. The total monetary values of the resources collected from Oak and Pine forests (Community and Government forest) are Rs. 139 and 45 per year respectively. And the resources include fodder, fuelwood, wood for agriculture implements, maturing leaves and minor forest produce (Negi and Bhat, 1993).

Green Accounting for Indian States and Union Territories Project: Monograph 4, was published as part of the Green Accounting for Indian States Project (GAISP). In this paper an attempt was made to value the biodiversity functions of India's natural ecosystems and framework was designed to adjust the national (GDP) and state income (GSDP) accounts. In this study, net consumer surplus estimates from ecotourism were given for different States and Union Territories in India. The authors found that the consumer surplus (domestic and foreign tourist) is Rs. 240 per hectare which is obtained by multiplying the consumer surplus per hectare attributable to tourists visiting the national parks with the number of domestic and foreign tourists where as the net present value of ecotourism for India was Rs. 65,193 per hectare. Various amounts were sanctioned for Indian States and Union Territories under different schemes for maintenance, and upkeep of national parks and wildlife sanctuaries for the year 2001/02. The total expenditure released for biosphere reserves, Project Elephant, Project Tiger, Eco development project, various central zoo authority was Rs. 116,476 million. Similarly, bio prospecting values were estimated for the whole of India, based on number of medicinal plants, number of species of conservation importance and based on all species, total values were Rs. 226,463,456 averaged as 144,539 per ha. Apart from these, there is a value that the global community would be willing to pay even if they have never used the fauna. These values are non-use values. According to the study the present non-use value was Rs. 773,077 per hectare. The final objective of the study was to incorporate the ecotourism and bio prospecting values of forests into the national accounts. The ecotourism values and bio prospecting values are taken in order to estimate the loss in value due to changes in dense forest cover for the year 2001 and 2003. Total NSDP for India was Rs. 16,387,941 million and total ESDP was Rs. 16,272,766 million and total loss as percentage of NSDP per year was -0.7.

Economic valuation of forests of Himachal Pradesh: The objective of this study (Verma, 2005) was to recognize the ecological contribution of forests in the economic development of the state. The study accounts for the monetary value of the forests of Himachal Pradesh using appropriate valuation methods. Forests Resource Accounting System was used to estimate the values. The study was based on the readily available data and no primary survey was conducted. The economic values were generated on annual basis – as per 2000 prices. The values were in the form of direct consumptive benefits of timber, fodder, fuelwood, NTFPs; direct non-consumptive benefits like ecotourism, recreational and indirect benefits like watershed benefits, carbon sink, micro–climate, biodiversity and employment generation. The total direct consumptive value was Rs. 10,830 million in which the monetary values of salvage, timber, fuelwood, fodder and minor forest produce were accounted. Direct non-consumptive benefits include ecotourism – the value was Rs. 66,570 million, where as indirect benefits include watershed, microclimatic factors, carbon sink, biodiversity and employment generation were Rs. 989,240 million. It was found that the GSDP of the state is Rs. 92,580 million, Total Economic Valuation of forests of Himachal Pradesh (as per current estimate) is Rs. 1,066,640 million and the corrected GSDP is Rs. 1,154,340, million i.e., 92.40% of corrected GSDP as forestry.

Economic valuation, green accounting and payment for environmental services for Himalayan forests of India: Forests provide wide range of Provisional, Regulating, Cultural and Supporting services from which people obtain multiple benefits. This paper (Verma *et. al*. 2010) explores the scope of valuation of forests ecosystem services so that they can be accounted into the national account of system. In this study four different scenarios were used to evaluate the ecosystem services of Himalayan forests. The first scenario for the valuation of forest ecosystem was based on the estimates of Costanza's framework (1997) in which values for 17 ecosystem system services were estimated for 5 different states mainly Arunachal Pradesh, Himachal Pradesh, Meghalaya, Sikkim, Uttarakhand specifically for tropical and temperate forests of hilly regions. The 16 ecosystem services accounted in this method were Forest cover (ha), Climate regulation, Disturbance regulation, Water regulation, Water supply, Erosion control and sediment retention, Soil formation, Nutrient cycling, Waste treatment, Biological control, Food production, Raw materials, Genetic resources, Recreational and Cultural. The total economic values of 16 ecosystem services for 5 respective states ranged from Rs. 25,952 to 539,234 per hectare per year. The second study was based on estimates of Green Accounting for Indian States (GIST) which was based on top-down macroeconomic approach. Following ecosystem services were considered for 5 different states (Arunachal Pradesh, Himachal Pradesh, Meghalaya, Sikkim and Uttarakhand): Timber and Fuelwood, Carbon, NTFP, Fodder, Soil Conservation, Water Augmentation, Flood Prevention, Recreation and Biodiversity. The economic values for above mentioned ecosystem services for 5 states were Arunachal Pradesh Rs.1,782,050 million, Himachal Pradesh Rs. 9,06,176 million. Meghalaya Rs. 462,424 million, Sikkim Rs. 54,240 million and for Uttarakhand Rs. 642,990 million. Net Present Value (NPV) was compiled by the Institute of Economic Growth (IEG), in recognition of the need for Net Present Value computations for estimating amounts to be paid for ecological restoration for the forestry area diverted into non-forestry area. Per hectare values given by NPV were used for the TEV calculations of forest ecosystem including -NTFP, carbon sequestration and eco-tourism values for five different states of India. This included Arunachal Pradesh, Himachal Pradesh, Meghalaya, Sikkim and Uttarakhand. Provisioning services included Timber, Fuelwood, NTFP; Regulating services include Carbon and Recreational services and Primarily Ecotourism. The total economic values for all five ecosystem services for five different states were Rs. 8,282 million, Rs. 8,691 million, Rs. 1,300 million, Rs. 1,943 million and Rs. 9,591 million per hectare respectively. The study has given a rough estimate for the comparison of Forestry contribution to GSDP and TEV values. The forest cover value for the year 2005 (SFR) was taken as a base year.

5.4. Limitations of studies

In India there have been a few studies aimed at assessing economic values of biodiversity and ecosystem services. The focus of assessments is largely on the use value or the marketable products (provisional services). There are a few state level assessments and only one national level assessment of the value of biodiversity and ecosystem services through green accounting. We observed several limitations of the studies and thus are of limited value in guiding policy making or pricing or costing for conservation and sustainable management of forest biodiversity and ecosystem services.

- Very few of the ecosystems / forest areas of the country have been covered in these studies; several critical areas have not been suitably covered. A glaring example of this is the North East India, home to a biodiversity hotspot and high forest cover.
- Almost all of the primary studies focus on one or a few of the ecosystem services arising from a forest ecosystem. These studies mostly focus on ecosystem services, which have use (direct/indirect) benefits including NTFPs, Timber, Ecotourism and Medicinal Plants, etc. Current markets already reward these services. This leads to an incomplete valuation, ignoring several important ecosystem services and hence not reflecting the true TEV of all services from the forests.
- Macro level studies at state or national level are largely based on secondary sources and international sources of the economic value of many products and services, which may have limited relevance to local situation.
- Sustainable rates of extraction and its implications for the valuation of forest products and services not addressed by most studies. Most studies estimate the value of current flow of product and services based on the current rates of extraction. It is quite likely that the rates of extraction of NTFPs and Fuelwood could be non sustainable.
- There are very few primary studies assessing economic valuation of non-use benefits. Most of the studies dealing with non-use values use wide approximations from global / international studies, hence lacking a local relevance.

- Most studies are based on case study approach, widely dispersed locations and often based on small samples consisting of one village or a cluster of villages or one forest type or one protected area, largely covering marketed products such as fuelwood, timber and NTFP.
- Most studies provide valuation of current flow of forest products and not covering future periods.
- Value of biodiversity and ecosystem services from the context of land use change to alternate uses is addressed only by a few studies for selected locations. Limited data is available on the cost of loss of biodiversity and ecosystem services due to conversion of forestland to non-forest purposes.
- Valuation is based on limited data on the use values and even more limited data for indirect use and non-use values of services.
- Biodiversity and ecosystem services are subjected to degradation and loss, however the extent and economic value of loss of biodiversity and ecosystem services due to different drivers is not addressed.
- Very limited assessment of drivers of changes or degradation of biodiversity and ecosystem services.
- The valuation studies rarely include ecological assessment of biodiversity. A few studies have estimated the carbon stocks.
- There is lack of consistency or uniformity in the methods of estimation or reporting of the values. Thus the studies are not comparable and cannot be aggregated. Some examples of inconsistency include the following;
  - Reporting Unit; per hectare, per household, per village, one forest type, one protected area, etc.
  - Stock value of products vs. flow of products and services
  - Period of reporting; per year, NPV over some years
  - Source of price of products/ service; current market price, willingness to pay, proxy prices of similar products, international price, etc.
  - Current rates of extraction or potential availability or supply of goods and services.

The TEEB India study presents a very good opportunity to address these limitations by enhancing geographical scope, coverage of services and using a methodological base that can provide a local context to valuation, which can later be used to develop policies and markets that stakeholders endorse.

6. How TEEB India Can Contribute to National Conservation Challenges?

The TEEB-India study is being proposed based on the lessons learnt from the global TEEB study and seeks to capture values of forest biodiversity and ecosystem services with a regional and local perspective across India. This chapter explores the potential role of the TEEB-India study in addressing conservation challenges highlighted in the earlier chapters. A summary of issues that could highlight how valuation of forest biodiversity and ecosystem services could assist in promoting conservation through policies, regulations and markets is presented in Table 2.11.

6.1. Policy implications for capturing the value

The current System of National Account (SNA) Statistics do not capture the extent and value of India's forest resources and ecosystem services. The Gross Domestic Product (GDP), which is the value in monetary terms of all goods and services produced in the economy in a given period of time, is the most important macroeconomic aggregate of National Accounts (http://mospi.nic.in/nscr/nas.htm). Under this current system only the use value and market-based commodities like timber and marketable NTFPs arising from the forestry sector are included. Although forests provide multiple benefits and cover 21% of the geographical area of India, the sector is estimated to contribute only about 1.5% to official GDP. Incorporating the available estimates of market and non-market value of forests can provide a powerful rationale to promote forest conservation (Costanza *et al.*, 1997). As the TEEB report states,

"Our valued natural capital is almost totally excluded from these accounts and its depreciation is not reflected in the macro-economic aggregates used by policy makers or discussed in the press. This means that fish stock losses, forest degradation, pollution and overuse of aquifers and species/habitat losses have little or no visibility in national accounting systems."
(http://www.teebweb.org/Portals/25/Documents/TEEB%20for%20POLICYMAKERS%20chapter%203.pdf).

In order to mainstream conservation of forest ecosystem services forest resources and assets in India need to be represented in our National Accounts in a holistic fashion. There are multiple approaches to achieve this. Murthy (2011) in his paper http://cwsc2011.gov.in/papers/seea/Paper_5.pdf notes these options as: "First one suggesting extension of conventional national income accounts by developing satellite accounts of environment and natural resources (SEEA) and another suggesting extension of input-output table of the economy" In addition he discussed that for the Indian context, "there is a possibility of considering another method by extending already well developed data systems of Annual Survey of Industries, and farm and forestry production accounts for estimating environmentally corrected value added."

This paradigm shift is severely limited at the moment by a lack of information, data and economic values of particularly non-use forest ecosystem services in India. TEEB-India study can play a critical role here by assessing economic valuation through developing methodology and a set of indicators for repetitive monitoring of change in the status and impact of policies on the ecosystem services. Thus a TEEB-India study will have to be initiated to generate primary data and economic values for different dominant forest ecosystems or types and services arising from critical forest ecosystems across the country.

6.2. Role of policy based instruments for optimizing the value

Appropriate changes to policies will play a vital role in recognizing and conserving forest biodiversity and ecosystem services. It will be worthwhile to assess our current policies including subsidies, incentives in line with changes in National Accounts owing to internalization of values of forest biodiversity and ecosystem services. There might be a realization that certain incentives, subsidies or taxes are perverse and on the other side there is a need for new ones to encourage investments in our natural assets. An example of this could be connecting the surrounding landscape with the management of a Protected Area (TEEB for Local and Regional Policy Makers) based on ecosystem services.

The reform in policy to achieve higher conservation results based on recognition of valuation of ecosystem services can be based on a variety of policy instruments that are available. This includes setting up Payment for Ecosystem Service (PES) schemes, providing subsidies, Integrated Conservation and Development Projects (ICDP), command-and-control regulation, environmental taxes, environmental subsidies etc, though all have their own pros and cons (Engel *et al.* 2008). India has experience in formulating and implementing many such instruments like CAMPA (http://envfor.nic.in/modules/recent-initiatives/campa/), the Green India Mission (http://moef.nic.in/downloads/public-information/GIM%20presentation%20Feb%2022%202011.pdf), the Thirteenth Finance Commission (http://fincomindia.nic.in), CDM in forestry and is preparing for REDD+, an international mechanism to promote conservation of forest carbon and biodiversity.

However, for several of the ecosystem services, it is critical that policy planning and developing instruments are based on a local context. The TEEB-India study will play a critical role in this regard by providing primary data and information on economic and ecological valuation of forest biodiversity and ecosystem services with a local context to different forest types and locations.

It is vital for state governments too to be involved in planning of adoption of such policy instruments, in consultation with and involving local communities and other stakeholders. This will complement policies and instruments adopted by the government of India. The TEEB report for Local and Regional Policy Makers provides a-6-step guidance on how to include ecosystem services in local and regional policy. The steps emphasize the need for inclusion of stakeholders in the planning and also in distribution of the services and allied benefits. The TEEB India study could identify components and stakeholders for this approach in geographies where ecosystem services are studied. This will form a very strong basis for eventually rolling out such policy based instruments in practice to promote conservation and enhancement of forest biodiversity and ecosystem services.

6.3. Role of market based instruments for optimizing the value of forest biodiversity and ecosystem services

In line with current accounting practices, the current markets do not capture total economic or ecological value of ecosystem services, leading to their loss and degradation. One of the ways to counter this is to reward best practices by developing markets for ecosystem services and also products and services that have reduced negative impacts. Market-based instruments follow from the concept of Payment for Ecosystem Services (PES), where beneficiaries of ecosystem services pay the providers of these services for their maintenance and upkeep (TEEB, 2010). Market-based instruments can include various options including establishment of carbon sequestration offsets, tradable development rights, eco-labeling and environment-certification and bio-prospecting etc. (IISD, 2006).

In the context of forestry and land use, there are a few instruments, which have been tried elsewhere and which could be implemented in India. This includes participating in and developing a market for forestry carbon offsets. India could actively participate in the upcoming REDD+ market or contemplate a domestic market. India could promote forest certification, where there are two existing dominant international standards, the PEFC and FSC and there is an increasing international demand for certified timber. Commercializing bioprospecting to pharmaceutical firms by making sure that there is sufficient contribution of the prospector towards conservation of the genetic resource and also paying royalties and upfront fees to local communities who are managers of this resource could be a useful strategy as well.

TEEB-India study will play a very critical role in developing India relevant market-based mechanisms, by assessing buyers and sellers of critical ecosystem services in Indian forests and also by providing them valuations and toolkits to negotiate and enter into contracts. Information and data generated will form a base for policymakers to setup overarching policy frameworks to allow these mechanisms to prosper. The emphasis to collect ground level data and engage with a series of stakeholders including local communities, and assessing the willingness of stakeholders at all levels to pay for conservation will ensure that these mechanisms are practical and hence can be implemented.

6.4. Implications for corporate decision making

Businesses utilize benefits from forest biodiversity and ecosystem services and impact the same, which they do not compensate for. This is because the non-use and indirect benefits are not captured in their financial accounting. This component of the TEEB India study should focus on identifying businesses, which are dependent on and are utilizing ecosystem services and biodiversity form India’s forests and assess the valuation of these, which needs to be internalized by these businesses. This is not only a conservation strategy but also a de-risking strategy for businesses dependent on these, as it would avoid a future scenario where depletion of these poses a risk to the existence of the business itself. Moreover, once accounted for and representing a substantial part of the raw material base and dependency, businesses can be encouraged to invest in conservation of these services. A good example of this on the benefit side is the ecotourism industry, dependent on the recreational and cultural value of India’s forests. Unless they invest in conservation of the forests, depletion could endanger ecotourism revenue and growth in the near future. TEEB India would give them a valuation and a framework and toolkit to base this investment on. Another example captured above is the pharma industry that depends on the forests for their genetic base for innovation. They need to be encouraged to pay for an Option value to preserve this genetic pool for future use.

On the impact side various industries can benefit by internalizing their impacts into mainstream decision-making, reflecting in the greening of their brand and also avoiding impending potential regulations. An example of this is the mining sector, which can include loss of biodiversity owing to its operations in its decision making process provided there is a large enough value on biodiversity. However, in order for companies to achieve this, they need to be able to assess and quantify their impacts on biodiversity and ecosystem services across their value chain. To achieve this, Life cycle assessment (LCA) techniques and environmental management systems need to be expanded and refined and TEEB-India could pride guidelines and tool kits to achieve this.

6.5. Implications for local communities

Currently local communities or their institutions such as Gram panchayats, Biodiversity Management Committees and Village Forest Committees do not have any access to the economic or ecological values of forest biodiversity and ecosystem services around them. They may be selling the products and services at lower values or may not even be getting any financial reward for having protected and managed these resources. TEEB-India study could generate economic and ecological values of forest biodiversity and ecosystem services and also provide simple toolkits and guidelines to enable them to account for the correct or total economic values in their dealing with market forces.

Table 2.11. Utility of valuation of biodiversity and ecosystem services

Instrument Target Group	Issue being focused	Potential options	TEEB's contribution
Internalizing Policy Implications - Ministry of Finance Planning Commission MOEF	The current System of National Account (SNA) Statistics do not capture the extent and value of India's forest resources and ecosystem services.	Adjustment to the SNA by following the SEEA 2003 or any alternate methodology which can lead to accounting of forest resources and forest ecosystem services in national income accounting and highlight at the national level a need to invest more capital towards managing natural assets. http://cwsc2011.gov.in/papers/seea/Paper_5.pdf https://unstats.un.org/unsd/envaccounting/seea.asp	A TEEB study to carry out valuation of forest ecosystem services in India can play a major role in providing methodologies, indicators and values for forest ecosystem services, which can be incorporated as Natural Capital into modified national accounts
Policy Based Instruments - MOEF State Forest Departments Ministry of Tourism	Policy failure to capture and address the environmental externalities of environmental growth leading to degradation of high biodiversity forest cover	Introducing new policy measures like taxes (e.g. CAMPA, coal cess etc.), incentives (e.g. REDD+ and 13th Finance Commission), taxable permits on extraction of resources, reforming subsidies which are harmful to the environment, participatory approach to policy formulation for NRM, addressing needs of local stakeholders with management/ tenurial rights on forests, develop frameworks for markets for ecosystem services.	TEEB-India study could assist governments with data and information to develop policies, incentives and taxes to account for forest biodiversity and ecosystem services
Market Based Instruments Buyer of ES (Public Sector, domestic and international corporations) Sellers of ES (local communities, Panchayats)	Market failure to capture full value of ecosystem services. Low provision of incentive to local communities to protect and conserve forest ecosystems.	Develop different market based solutions like ecotourism, eco-labeling, bio-prospecting, cap and trade of offsets, biodiversity banking and other Payment for Ecosystem Services frameworks.	A detailed TEEB study based on primary research and pilot projects will identify critical ecosystem service, their users and suppliers. This will form a basis for structuring instruments such as Payment for Ecosystem Services and contracts.

Internalization of Environmental Externalities Public and Private Corporations	Businesses utilize forest ecosystem services and biodiversity causing damage to the same, which is not compensated for since the non-use and indirect benefits are not captured in their financial accounting.	Valuation of indirect use and non-use forest ecosystem services and biodiversity and internalizing the same in corporate financial accounts, leading to more efficient use and less impact. Creation of more biodiversity business opportunities.	TEEB will carry out valuation of forest ecosystem services and biodiversity and analyze impacts. TEEB will account investment being made to maintain these. This will feed into mainstreaming of these into corporate spending.
Absence of value data to Local community institutions	Local community institutions do not have data on the economic values of forest biodiversity and ecosystem services, so they do not get adequate compensation	Access to information and data on economic values of forest biodiversity and ecosystem services would assist community institutions to demand and charge correct price for the commercial users	TEEB-India study could develop simple guidelines and toolkits to enable community institutions in demanding correct price for the goods and services

7. Proposed Methodology

It is very clear from the review of the state of forests and ecosystem services as well as the review of studies on the economic valuation of biodiversity and ecosystem services that there is very limited knowledge, information and database to assist in policy making or decision-making to promote conservation and restoration. The need for TEEB-India study can be highlighted based on the vision of TEEB (2010) - "Biodiversity in all its dimensions – the quality, quantity and diversity of ecosystems, species and genes – needs to be preserved not only for societal, ethical or religious reasons but also for the economic benefits it provides to present and future generations. We should aim to become a society that recognizes measures, manages and economically rewards responsible stewardship of its natural capital". Further, TEEB studies have the potential to make significant changes in the way we manage nature, based on economic concepts and tools. TEEB calls for "wider recognition of nature's contribution to human livelihoods, health, security, and culture by decision makers at all levels (national and local policy makers, administrators, businesses and citizens). It promotes the demonstration and (where appropriate) the capture of the economic values of nature's services through an array of policy instruments and mechanisms, some of which are market-based" (TEEB, 2010).

The lack of complete valuation, incomplete coverage of services and lack of local context pose a severe limitation in usability of these studies by policy makers and other stakeholders in India to move towards a new socio-economic and policy regime that promotes higher consideration and conservation of forest stock as compared to alternate land uses. The studies are not comparable due to differences in the methods, ecosystem services covered and modes of reporting. Thus there is a clear rationale for not only launching of TEEB-India study but also to implement the potential recommendations of such a study to enable conservation, restoration and rewarding of the communities and nations managing the biodiversity and ecosystem services. Here an approach, methodology and institutional arrangement for implementing a TEEB-India study are presented.

7.1. Rationale for TEEB-India study in Forest Sector

Growing human population, economic development and technological revolution has increased the demand for forest land and goods and services from forest ecosystems. This increasing dependence of human society has led to degradation of forests and biodiversity. This has implications for sustaining biodiversity, biomass production, fresh water supply, etc. Addressing these challenges requires as a first step, knowledge, information and database about the status of forest ecosystems, biodiversity and flow of ecosystem services. Currently there is limited information and knowledge, resulting in inadequate appreciation of the forest ecosystem services delivered, specially its economic value both on the current and future time-scales. The utility of valuation of forest biodiversity and ecosystem services to different stakeholders is presented in Table 2.11. Further rationale for the economic valuation forest biodiversity and ecosystem services is as follows:

- Methodology and a good database on economic valuation of biodiversity and ecosystem services can contribute to integration of natural resource assets in National Accounting and in calculation of the GDP of a country.
- Addressing local and global environmental challenges relevant to forest ecosystems requires policies, institutional arrangements, financial investments and technological interventions to promote conservation and sustainable management. Conservation and restoration of forest ecosystems would also require incremental investments and regulating extraction of forest goods and services. Thus, the decision makers have to find resources and justification for dedication of financial and other resources. Economic valuation of the ecosystems services derived from forest ecosystems will assist the decision makers to rationalize the need for investment in conservation and restoration and on regulating the extraction.
- Economic valuation would help decision makers to choose between the current mode of using the forest biodiversity and ecosystem services or alternate options, such as conversion of forests to cropland / infrastructure or retaining forestland as forestland.
- Cost-benefit analysis of the ecosystem services delivered under the current practices compared to the alternate options would help decision makers to make the appropriate choice, to ensure sustained delivery of ecosystem services to the human society and the environment.
- Economic valuation of the ecosystem services would help in choosing the option of conservation as compared to exploitation or non-sustainable use of forest biodiversity and ecosystem services.
- Economic valuation assists in recognition of the importance of specially the non-monetary benefits from forest ecosystems.
- To evaluate the overall contribution of ecosystems to social and economic status of human societies and also to understand how and why humans use ecosystems and to the relative impact of alternative actions so as to help guide decision-making.
- Knowledge of status and degradation of biodiversity and ecosystem services and potential non-sustainable extraction and management practices is necessary to initiate research to develop sustainable management and extraction of biodiversity and ecosystem services.
- The outputs of the TEEB-India study could assist policy makers from the Government of India to gram panchayats and biodiversity management committees in effective management of the forests due to the potential high value.
- Since there is international trade in wildlife and forest products, often the degradation of forests could be due to international market demand. Knowledge of the high value of the biodiversity and ecosystem services could create awareness in local communities to law-enforcing agencies.

7.2. Target groups for TEEB-India study

There are a number of stakeholders involved in managing the forests and biodiversity. Different stakeholders have different role in promoting conservation and restoration of forest ecosystems and biodiversity. Potential target groups for TEEB-India study include the following:

- Government of India, Ministry of Environment and Forests, Ministry of Finance, National Biodiversity Authority, Planning Commission, State Governments and Forest Departments. These institutions need economic valuation database and information for national accounting of green services and policy making to promote conservation and sustainable use of forest biodiversity and ecosystem services.
- Gram panchayats, Biodiversity Management Committees, Village Forest Committees. The findings of TEEB-India study could help these local decision makers in taking decisions on sustainable extraction, charging appropriate

fee for extraction to non-village users and in protection and management of forests.

- Corporate and private sector: TEEB-India outputs could help corporate and industry to consider the correct value of the natural resources from the forests that they would be using and also in pricing of the products and in developing market mechanisms to internalize the environmental cost of loss or even protection of biodiversity and ecosystem services.
- Consumers: Awareness to consumers about the economic value of the products and services obtained from forests would help them to use resources prudently and in enabling willingness to pay for the ecosystem services.
- Multilateral and bilateral agencies: Economic valuation of biodiversity and ecosystem services would assist international agencies to enforce international laws on conservation and sustainable use. Further, all bilateral and multilateral agencies could incorporate the economic value of biodiversity and ecosystem services in all their projects and programmes.

7.3. Elements of TEEB-India assessment

The elements or components of TEEB-India study would include multiple steps, starting from identifying the target groups, selecting the forest types or strata, identification of the ecosystem services, indicators for assessing them, methods for estimation of the economic value, institutional arrangements and a time frame for the study. These elements are listed in below:

- Identify target groups for TEEB-India outputs
- Objectives and outputs of TEEB-India assessment
- Stratify forests for TEEB-India assessment
- Identify ecosystem services from forests
- Assess status of forests, biodiversity and ecosystem services - focusing on assessing stocks, flows, change in ecosystem services and biodiversity across various scenarios of land use transformation and development of baseline scenario
- Develop indicators for each ecosystem service
- Select methods and sampling procedures
- Conduct field studies, modeling and analysis
- Document successful case studies demonstrating application of valuation of ecosystem services
- Conduct stakeholder survey for assessing Willingness to Pay
- Prepare target stakeholder-oriented TEEB-India reports
- Develop an approach to utilizing the knowledge of TEEB-India in planning, decision making, marketing, etc.
- Timeline for the TEEB-India study
- Institutional arrangements for TEEB-India assessment.

7.4. Stratification and selection of forest types

Forests are diverse with respect to biodiversity, species dominance, tree density and crown cover and flow of ecosystem services. Biodiversity and ecosystem services vary with forest types mainly and also to some extent on the mode of management. Here we focus on the ecological types. Forest Survey of India has stratified forests in India into 16 forest types (Table 2.9) following the Champion and Seth classification (1968). The dominant forest types include tropical dry deciduous (42% of forest area), tropical moist deciduous (20%), tropical semi-evergreen (14%), himalayan moist temperate (4%), and these four types account for about 80% of the total forest area (ISFR, 2012). A decision has to be taken to whether to select all the 16 forest types or to select a sub-set of only the dominant forest types, keeping in mind the resource and time constraints.

State-forest type strata

It is very important to consider the scale of assessment for TEEB-India - at national, state, district or forest type level. The focus of the study could be at the national and state level according to forest types given the role of the central and state governments in policy making. Thus it is necessary to develop spatial maps overlaying state boundaries with forest type boundaries to select “state-forest type strata”. Ideally all forest types, regions and socio-economic systems should be selected for the study. But if resource limitations exist, then to select the state-forest type strata, the following approach could be adopted.

- Divide India into 5 zones - North, South, East, West and Central

- Further, it may not be feasible to select locations covering all states and forest types in a zone, a map overlaying the states and forest types need to be prepared and used in selecting the dominant state-forest type strata and locations.
- The final decision on the selection of states and forest types could be made by the Steering Committee based on secondary data, information and the maps.

In addition to forest types according to Champion and Seth classification, there are other forests such as farm forestry and social forestry plantations, agro-forestry systems and homestead gardens. The decision on selection of number of forest types, stratification and inclusion of farm forestry, agro-forestry, etc., could be taken at an expert consultation workshop at the beginning of the project to provide feedback to the Steering Committee.

Two biodiversity hotspots

In addition to the 5 zones, the Western Ghats and the Eastern Himalayas which are two biodiversity hotspots of India could be selected for the TEEB-India study. These two locations, apart from being biodiversity hotspots are regions of origin of several important river systems and also have a diversity of habitats.

Case studies

In each of the selected state 'forest type-strata', the study teams could identify one or two successful case studies of operationalizing the concept of valuation of forest biodiversity and ecosystem services and utilizing such information in decisions in managing or extraction or charging of products and services.

Forestland conversion and transition scenarios

Conversion of forestland to other uses could lead to potentially complete loss of biodiversity and ecosystem services and thus it is suggested to incorporate potential scenarios of forestland conversion to alternate uses in each of the 'forest type-strata' under the TEEB-India study.

7.5. Identification of biodiversity components and ecosystem services

The next step is to identify the ecosystem services. The ecosystem services could include; provisioning, regulating, cultural and supporting services based on MA (2005) and TEEB (2010). Not all services may be relevant to a given state or forest type and could vary from location to location even within a forest type. Thus there is a need to identify and prioritize biodiversity and ecosystem services relevant to a state-forest type strata, based on;

- Literature available for the region/forest type
- A pilot survey of the forests and consultations with the relevant stakeholders such as;
  - Gram panchayats, Village Forest Committees, Biodiversity Management Committees, etc.
  - Forest department, State Governments
  - Corporate and NGOs.

7.6. Assessment of status of forests and biodiversity and development of baseline scenario

It is very important to assess the extent and status of forests, ongoing forest conversion to different land uses, status of biodiversity, crown density, degradation and loss of forests and biodiversity. Information on the status of forests and biodiversity is necessary to link the economic value of biodiversity and ecosystem services to the observed status of forests and its conversion to other uses. The assessment could be made according to 'state-forest type' strata. The methods for such an assessment would involve use of remote sensing techniques, field ecological studies and socio-economic surveys. The outputs of such an assessment could include the following:

- Area under forest type in a given state
- Forest land use conversions from forest to non-forest uses
- Tree crown cover and tree density
- Species composition, distribution, dominance - herbs, shrubs and trees
- Biodiversity, carbon stocks, extraction of goods and services.

These studies would lead to development and establishment of a baseline scenario of the forest and biodiversity status for comparison with alternate uses as well as long-term monitoring of changes in biodiversity and ecosystem services.

7.7. Developing indicators for ecosystem services

To assess the status or value of the ecosystem services, there is a need for identifying indicators. For a given ecosystem service, there could be one or multiple indicators. Indicators could be ecological, economic, social and cultural. The indicators could be identified from:

- Literature review
- Expert consultation

Potential examples of indicators for forest biodiversity and ecosystem services are:

- Biodiversity
  - Biodiversity index
  - Species dominance
  - Number of NTFP species extracted or quantities consumed
- Ecosystem services
  - Fresh water: Ground water depth and rates of depletion, stream flow rate
  - Climate regulation: CO_2 emissions or removals from forest in million tones/year
  - Carbon sequestration: Carbon stocks per hectare or stock changes /ha/year
  - Food: Tonnes of food produced, diversity of foods consumed.

The selection of indicators for assessing the forest biodiversity components and ecosystem services for investigation and valuation should be based on secondary information and consultation workshop of experts.

7.8. Selection of methods

The TEEB-India study would involve measurement estimation and modeling of indicators for the identified ecosystem service. The methods could include remote sensing, field ecological methods, socio-economic surveys, economic valuation methods and stakeholder consultations. The method would be indicator specific. The key steps in the method would involve (refer to TEEB, 2010, Ravindranath and Ostwald, 2008; IPCC, 2006; Ravindranath *et al.*, 2012):

- Identification of the service and indicators for estimation
- Adoption of the 'state-forest type' strata and define the boundary of forest type within the state
- Sampling procedures and sample size estimation
- Selection of sample locations
- Selection of ecosystem services and the relevant indicators
- Selection of methods to estimate the indicators; ecological, economic valuation and socio-economic survey
- Laying of plots for ecological studies and selection of villages or markets for socio-economic survey
- Conduct measurements, surveys and gather data, maps, information, etc.

Shared and consistent methodology: In a national level study, involving many forest types, states and institutions, it is very important to ensure consistent methodology to enable comparison and aggregation of data and findings.

Expert consultation and workshops: Given the complexity of the methods involved (ecological, economic, social, market, etc.), it is very important to have consultation workshops of experts, particularly the ecologists, economists and social scientists for selecting and standardizing the methods to be adopted across the states and institutions.

7.9. Field studies, modeling and data analysis

Conduct field studies to gather data on the ecological, economic, market, social and institutional aspects for the selected 'state-forest type' strata. Field studies and data analysis would involve the following aspects:

- Seasonality and periodicity of field studies: It is very important to decide the season and months for data collection and the periodicity if necessary.
- Types of studies:
  - Secondary data and maps
  - Ecological studies
  - Socio-economic survey: Household survey, Participatory rural appraisal, focus-group discussion, etc
  - Remote sense data analysis
  - Market survey
- Data entry, compilation and verification:

- Data analysis and archiving
- Modeling

7.10. TEEB-India report for stakeholders

The final step in economic valuation of biodiversity and ecosystem services would involve compilation and synthesis of the findings of the TEEB-India study. The need for information on TEEB would vary from stakeholder to stakeholder, depending on the utility of biodiversity and ecosystem services. Thus, the TEEB reports have to be prepared for different stakeholders such as the Government of India/ state governments/planning commission/forest departments, corporate, industries, gram panchayats and biodiversity management committees. It may be useful to provide guidelines or toolkits to different stakeholders on how to extract and use data and information, extrapolate and interpolate for different periods and for different scenarios of forestland conversion, different market prices and supply levels.

7.11. Utilizing TEEB-India outputs

The ultimate purpose of the TEEB-India study should be to generate information, knowledge and database for different stakeholders to enable them to promote conservation, sustainable utilization, internalization of environmental externalities and in deriving correct price for biodiversity and ecosystem services, especially for the local communities. The utility of the TEEB-India assessment is presented in Section 6. It would assist in the following manner.

- Providing methodology and database for capturing the total economic value of biodiversity and ecosystem services, for example in System of National Account or in GDP calculations
- Developing policy based instruments such as taxes, levies and incentives
- Developing market based instruments such as eco-labeling, payment for ecosystem services, bio-banking, forest certification, etc.
- Assisting corporates in decision-making on internalizing the externalities of loss of biodiversity or ecosystem services
- Local communities in decisions on rates of extraction, utilization and pricing of the biodiversity and ecosystem services.
- Creating awareness in consumers about the value of forest biodiversity and ecosystem services to promote sustainable harvested products and willing to pay for the ecosystem services.
- Developing policies, programmes, market mechanisms, regulations, etc., to promote conservation and correct costing and pricing of ecosystem services.

8. Challenges of TEEB-India Study

In India, there have been a few efforts at evaluating biodiversity and ecosystem services, including a few at the national and state level and many case studies around the country covering a village to a cluster of villages or a forest type. Currently, these studies cannot be compared or aggregated due to differences in the ecosystem services, methods, periods of the study, scale and the differing focus. The TEEB-India study would be a large study covering all the forest types, regions and socio-economic systems. The challenges that TEEB-India study could potentially face and options to address them are as follows:

- **Scale and diversity of forest ecosystems:** India has 15 forest types, 35 states and 7 union territories, a diversity management systems, tenure and forest quality. Thus it will pose a challenge in the selection of large number of locations for the study.

  To address this, the study has proposed selection of five 'state-forest type zones' and two biodiversity hotspots, including case studies.
- **Varied socio-economic status or pressures:** The forests in different parts of India are subjected to different levels of socio-economic pressures. For example, evergreen forests in the Western Ghats have different socio-economic stresses compared to the northeast.

  This issue could be addressed during the selection of sites in each of the five zones by the Steering Committee, based on secondary data and maps. Further, case study approach could be adopted.

- **Methodological complexities:** TEEB-India study would require methods from economics, ecology, sociology, remote sensing, soil science, hydrology and marketing. Further, economic valuation may have to be carried out for several non-use services and intangible benefits from forests, which are not easy to quantify and monetize.

  Based on the TEEB studies conducted in different parts of the world, and by involvement of Indian experts, it is possible to select feasible methods for economic valuation of different indicators.

- **Multi-period measurements:** Monitoring of some of the ecosystem services such as soil carbon stock changes, reduction in soil erosion, ground water recharge and water run-off would require multi-period visits and measurements.

  In a 2-year study involving one year of field study, it is proposed to adopt cross-sectional studies, control plots or groups and use of remote sensing and secondary data to generate information on the rates of change in the flow of ecosystem services.

- **Sampling:** Given the large diversity of forest types, states, socio-economic pressures etc., selecting samples for different studies would be a challenge. The study may have to select a large number of samples from even remote locations contributing to the high cost of the study.

  Sample size will be determined based on preliminary studies on the variations in different indicators, the cost of sampling and the number of indicators to be monitored.

- **Availability and access to data:** The TEEB-India study would require secondary data, different types of maps, remote sense data, market value of different products and services, especially for the non-use services, and the land use conversion data.

  Efforts will be made to obtain all the maps from different government institutions such as the Forest Survey of India, National Remote Sensing Centre and National Bureau of Soil Science and Land Use Planning through the Ministry of Environment and Forests, which is the nodal Ministry for the TEEB-India study.

- **Networking of institutions:** A large number of diverse institutions and experts will be involved in the study and it will be a challenge to network and coordinate.

  In India there are several networks on biodiversity and climate change and further, many all India coordinated programmes are being implemented in agriculture and forestry sectors, which would act as models for this study.

- **Timeline for the studies:** A TEEB study which generates values for the stocks as well as flows of biodiversity and ecosystem services would require a multi-year study, which may not be feasible.

  The proposed TEEB-India study is for a period of 2 years in which field studies could be carried during one year. After the completion of the TEEB-India study, Government of India could potentially initiate long-term monitoring of biodiversity and ecosystem services.

- **Mainstreaming TEEB in planning:** Even if a TEEB study is successfully completed and all the required data and information generated, its utilization in planning and implementation of conservation and developmental programmes involving biodiversity and ecosystem services would be a challenge. The willingness-to-pay among the different stakeholders for biodiversity and ecosystem services will be a challenge.

  There is increasing awareness among the corporates, mass media and many consumers about the value of biodiversity and ecosystem services, which would enable implementation of the findings of the study. Further, Government of India has many legislations and regulations with respect to conversion and use of forestland and products accruing from them, which could be strengthened based on data and information from valuation of biodiversity and ecosystem services.

References

Afreen, S. Sharma, N. Chaturvedi, R.K. Gopalakrishnan, R. Ravindranath, N.H. (2011). "Forest Policies and Programs Affecting Vulnerability and Adaptation to Climate Change". Mitigation and Adaptation Strategies for Global Change, 16(2): 177-197.

Appasamy, P. P. (1993). "Role of Non-Timber Forest Products in a Subsistence Economy: The case of a Joint Forestry Project in India". Economic Botany, 47(3): 258 - 267.

Badola, R. Hussain, S.A. Mishra, B.K. Konthoujam, B. Thapliyal, S. and Dhakate, P.M. (2010). "An assessment of ecosystem services of Corbett Tiger Reserve, India". Environmentalist, 30: 320–329.

Bahuguna, V.K. and Upadhyay, A. (2002). "Forest fires in India: Policy initiatives for community participation". International Forestry Review, 4(2).

Bawa, K.S. & Godoy, R. (1993). "Introduction to Case Studies from South Asia". Economic Botany, 47(3): 248–250.

Bolin, B. Ciais, P. Cramer, W. Jarvis, P. Kheshgi, H. Nobre, C. Semenov, S. & Steffen, W. (2000). "Global perspective. In: Watson, R.T. *et al.* (eds.). Land use, land-use change, and forestry". A special report of the IPCC. Cambridge Univ. Press. Cambridge. 23–51.

Botanical Survey of India (BSI), Government of India, (2009).

Champion, H.G. and Seth, S.K. (1968). "A Revised Survey of The Forest Types of India". Government of India Publications. Delhi.

Chopra, K. (1993). "The Value of Non-Timber Forest Products: An URL: Estimation for Tropical Deciduous Forests in India". Economic Botany, 47(3): 251–257.

Chopra, K. (1993). "The valuation of biodiversity within protected areas: alternative approach and a case study". Institute of Economic Growth, Delhi.

Costanza, R. Arge, R. Groot, R.D. Farberk, S. Grasso, M. Hannon, B. Limburg, K. *et al.* (1997). "The value of the world's ecosystem services and natural capital". Nature, 387(May): 253–260.

Duraiappah, A.K. (2006) "Markets for Ecosystem Services A Potential Tool for Multilateral Environmental Agreements". IISD.

Dwivedi, P. Rathore, C.S. and Dubey, Y. (2009). "Ecological benefits of urban forestry : The case of Kerwa Forest Area (KFA), Bhopal, India". Applied Geography, 29(2): 194–200.

Engel, S., S. Pagiola and S. Wunder (2008) "Designing payments for environmental services in theory and practice: An overview of the issues". In: Ecological Economics 65, p. 663-674.

FAO, (2010). "Global Forest Resources Assessment, 2010, FAO Forestry Paper 163, Food and Agriculture Organization, Rome, 2010".

Farber, C.S. Costanza, R. and Wilson, A.M. (2002). "SPECIAL ISSUE: The Dynamics and Value of Ecosystem Services: Integrating Economic and Ecological Perspectives, Economic and ecological concepts for valuing ecosystem services". Ecological Economics, 41: 375–392.

FSI. (1995). State of Forest Report, 2005, Forest Survey of India, Ministry of Environment and Forests, Dehra Dun, India.

GIST. (2006) "The value of timber, carbon, fuelwood and non-timber forest products in India's forests." Green Indian States Trust.

Gautam, P.L., Jacob, C.T., Venkataramani, G. and Singh, Y. (2010). "Biodiversity and Indian Economy". Think India Quarterly 13(3): 182-197.

Gopalakrishnan, G., Negri, M.C., and S.W. Snyder. (2011). "A Novel Framework to Classify Marginal Land for Sustainable Biomass Feedstock Production". Journal of Environmental Quality, 40: 1593-1600.

Gundimeda, H. Sanyal, S. Sinha, R. and Sukhdev, P. (2005). "The Value of Timber, Carbon, Fuelwood, and Non-Timber Forest Products in India's Forests". Green Accounting for Indian States Project Monograph 1.

Hadker, N. Sharma, S. David, A. and Muraleedharan, T.R. (1997). "Willingness-to-pay for Borivli National Park: evidence from a Contingent Valuation". Ecological Economics, 21: 105–122.

India State of Forest Report (ISFR), (2011). "Forest Survey of India (Ministry of Environment & Forests), India".

India's Fourth National Report to the Convention of Biological Diversity. (2009). Ministry of

Environment and Forest, Government of India, New Delhi.

IPCC, (2006). “Guidelines for National Greenhouse Gas Inventories”. Vol.4 AFOLU (agriculture, Forestry and other Land Use), Kanagawa, Japan (also available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html).

Joshi, G. and Negi, G.C.S. (2011).”Quantification and valuation of forest ecosystem services in the western Himalayan region of India”. International Journal of Biodiversity Science, Ecosystem Services & Management, 7(1): 2–11.

Kadekodi, G.K. and Ravindranath, N.H. (1997). “Macro-economic analysis of forestry options on carbon sequestration in India”. Ecological Economics, 23: 201–223.

Kiran, G.S. and Kaur, M.R. (2011). “Economic valuation of forest soils”. Current Science, 100(3): 3–6.

Kirschbaum, M.U.F. Fischlin, A. Cannell, M.G.R. Cruz, R.V.O. Cramer, W. Alvarez, A. Austin, M.P. Bugmann, H.K.M. Booth, T.H. Chipompha, N.W. S. Cisela, W.M. Eamus, D. Goldammer, J.G. Sellers, A.H. Huntley, B. Innes, J.L. Kaufmann, M.R. Kräuchi, N. Kile, G.A. Kokorin, A.O. Körner, C. Landsberg, J. Linder, S. Leemans, R. Luxmoore, R.J. Markham, A. McMurtrie, R.E. Neilson, R.P. Norby, R.J. Odera, J.A. Prentice, I.C. Pitelka, L.F. Rastetter, E.B. Solomon, A.M. Stewart, R. Minnen, J.V. Weber, M. and Xu, D. (1996). “Climate change impacts on forests. In: Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analysis”. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change [Watson, R.T. Zinyowera, M.C. and Moss, R.H. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 95–129.

Kumar, P. Sanyal, S. Sinha, R. and Sukhdev, P. (2006). “Accounting for the Ecological Services of India’s Forests: Soil Conservation, Water Augmentation and Flood Prevention”. Green Accounting for Indian States Project Monograph 7.

Lal, M. and Singh, R. (2000). “Carbon sequestration potential of Indian forests”. Environmental Monitoring and Assessment, 60: 315–327.

MA (Millennium Ecosystem Assessment), 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington D.C.

Mahapatra, A.K. and Tewari, D.D. (2005). “Importance of Non-timber Forest Products in the Economic Valuation of Dry Deciduous Forests of India”. Forest Policy and Economics 7: 455–467.

Mittermeier, R.A. Myers, N. Gill, P.C. Mittermeier, C.G. (2001). “Hotspots: Earth’s Richest and Most Endangered Terrestrial Ecoregions”. Mexico City: CEMEX.

Murthy, I. K. Bhat, P.R. Ravindranath, N.H. and Sukumar, R. (2005). “Financial valuation of non-timber forest product flows in Uttara Kannada district, Western Ghats, Karnataka”. Current Science, 88(10): 1573–1579.

Murthy, M.N. (2011). “Environmental Valuation and Accounting in India and UN Method of SEEA for Estimating Green GDP”. Paper for 15th Conference of Commonwealth Statisticians, New Delhi, India.

Myers, N. (1988). “Threatened Biotas: “Hot Spots” in Tropical Forests”. The Environmentalist 8(3):187-208.

Narendran, K. Murthy, I.K. Suresh, H.S. Dattaraja, H.S. Ravindranath, N.H. Sukumar, R. (2001). “Non timber Forest Product Extraction, Utilization and Valuation: A Case Study from the Nilgiri Biosphere Reserve, Southern India. Economic Botany, 55: 528–538.

National Biodiversity Action Plan (2008). Ministry of Environment and Forest, Government of India, New Delhi.

Negi, G.C.S. and Bhatt, Y.D. (1993). “Biomass utilization in a Central Himalayan village ecosystem. In: Vir Singh (ed.), Ecocrisis in the Himalaya. IBD, Dehradun: 133-146.

Negi, G.C.S. and Semwal, R.L. (2010). “Valuing the Services Provided by Forests in the Central Himalaya”. Mountain Forum Bulletin, (January): 44–47.

Parikh, J. Singh, V. Sharma, S. and Buragohain, C. (2008). “Natural Resource Accounting in Goa - Phase II”.

Pearce, D.W. and Warford, J.W. (1993). “World without End: Economics, Environment, and Sustainable Development”. Oxford University Press, Oxford.

Pride, W.M. & Ferrell, O.C. (1993), Marketing, 8th ed., Houghton Mifflin, Boston, MA.

Purushothaman, S. Viswanath, S. and Kunhikannan, C. (2000). "Economic valuation of extractive conservation in a tropical deciduous forest in Madhya Pradesh , India". Tropical Ecology, 41(1): 61–72.

Ralhan, P.K. Negi, G.C.S. and Singh, S.P. (1991). "Structure and functioning of the agro-forestry system in the Pithoragarh district of central Himalaya: an ecological view point". Agriculture, Ecosystems and Environment, 35: 283-296.

Rana, B.S. Singh, R.P. and Singh, S.P. (1989). "Carbon and energy dynamics of seven central Himalayan Forests". Tropical Ecology 30(2): 253-264.

Ravindranath, N.H. Srivastava, N. Murthy, I.K. Malaviya, S. Munsi, M. Sharma, N. (2012). "Deforestation and forest degradation in India-Implications for REDD+". Current Science 102(8): 1117-1125.

Ravindranath, N.H. and Ostwald, M. (2008). "Carbon Inventory Methods – Handbook for Greenhouse Gas Inventory, Carbon Mitigation and Roundwood Production Projects". Advances in Global Change Research, pp. 304.

Sahney, S. Benton, J.M. And Lang, H.J.F. (2010) "Rainforest Collapse Triggered Carboniferous Tetrapod Diversification in Euramerica". Geology, 38: 1079-1082.

Sarmah, R. and Arunachalam, A. (2011). "Contribution of Non-Timber Forest Products (NTFPS) To Livelihood Economy of the People Living In Forest Fringes in Changlang District Of Arunachal Pradesh, India". Indian Journal of Fundamental and Applied Life Sciences, 1(2): 157–169.

Singh, J.S. and Singh, S.P. (1992). "Forests of Himalaya: Structure, Functioning and Impacts of man". Gyanodaya Prakashan, Nainital: 294.

Singh, S. P. (2007). "Himalayan Forest Ecosystem Services: Incorporating in national accounting". Environment.

Somashekar, R.K. Nagaraja, B.C. and Urs, K. (2007). "Monitoring of Forest Fires in Bhadra Wildlife Sanctuary". J. Indian Soc. Remote Sens, 36: 99-104.

The Economics of Ecosystems and Biodiversity (TEEB) for National and International Policy makers (2009)

The Economics of Ecosystems and Biodiversity: The Ecological and Economic Foundations (2010).

URL:(http://envfor.nic.in/modules/recent-initiatives/campa/)

URL: (http://fincomindia.nic.in)

URL: (http://mospi.nic.in/nscr/nas.htm)

URL:(http://www.fao.org/docrep/x5303e/x5303e05.htm)

URL: http://cwsc2011.gov.in/papers/seea/Paper_5.pdf

URL: http://thewesternghats.in/browsechecklists.

URL: http://www.biodiversityhotspots.org

URL: http://www.wii.gov.in/envis

URL:www.wii.gov.in/indianfauna/globally%20threatened%20indian%20fauna.pdf

URL:(http://moef.nic.in/downloads/publicinformation/GIM%20presentation%20Feb%2022%202011.pdf)

URL:http://cwsc2011.gov.in/papers/seea/Paper_5.pdf

URL:http://www.teebweb.org/Portals/25/Documents/TEEB%20for%20POLICYMAKERS%20chapter%203.df

URL:https://unstats.un.org/unsd/envaccounting/seea.asp

Ved, D.K. and G.S. Goraya, (2007). "Demand and Supply of Medicinal Plants in India. NMPB, New Delhi & FRLHT, Bangalore, India".

Verma M. Vijayakumar C.V.R.S. Phukan B.R. Yadav A. and Rakshit A. (2006). "Proposed Methodological Framework and Data Issues for Physical Accounting of Forestry Resources: Learning from the States of Madhya Pradesh and Himachal Pradesh. Statistical Accounting of Land and Forestry Resources". 197-198.

Verma, M. (2000). "Economic Valuation of Forests of Himachal Pradesh".

Verma, M. (2005). "Use of the Green Accounting Approach to Assess the Contribution of Watershed Values of the Forestry Sector to the Gross Domestic Product of Himachal Pradesh".

Verma, M. Bhagwat, S. Negandhi, D. and Sikka, M. (2010) "Economic valuation, green accounting and payment for environmental services –gears of the toolkit for tackling impacts of climate change in Himalayan forests of India". Subtheme: Forest restoration and climate. 18th Commonwealth Forestry Conference.

Verma, M. Joshi, J. Godbole, J. and Singh, A. (2007). "Valuation of Ecosystem Services and Forest Governance, A scoping study from Uttarakhand".

Vos. C.C. Berry, P. Opdam, P. Baveco, H. Nijof, B. O'Henely, J. Bell. C. and Kuipers, H. (2008). "Adapting landscapes to climate change: examples of climate-proof ecosystem networks and priority adaptation zones". Journal of Applied Ecology 2008, 45: 1722–1731.

Zobel D.B. Singh S.P (1997). "Himalayan forests and Ecological generalization". Bio Sci., 47(11): 735-745.

Zoological Survey of India (ZSI), Government of India, (2008).

Annexure 2.1.

Synthesis of the literature on valuation of biodiversity and ecosystem services

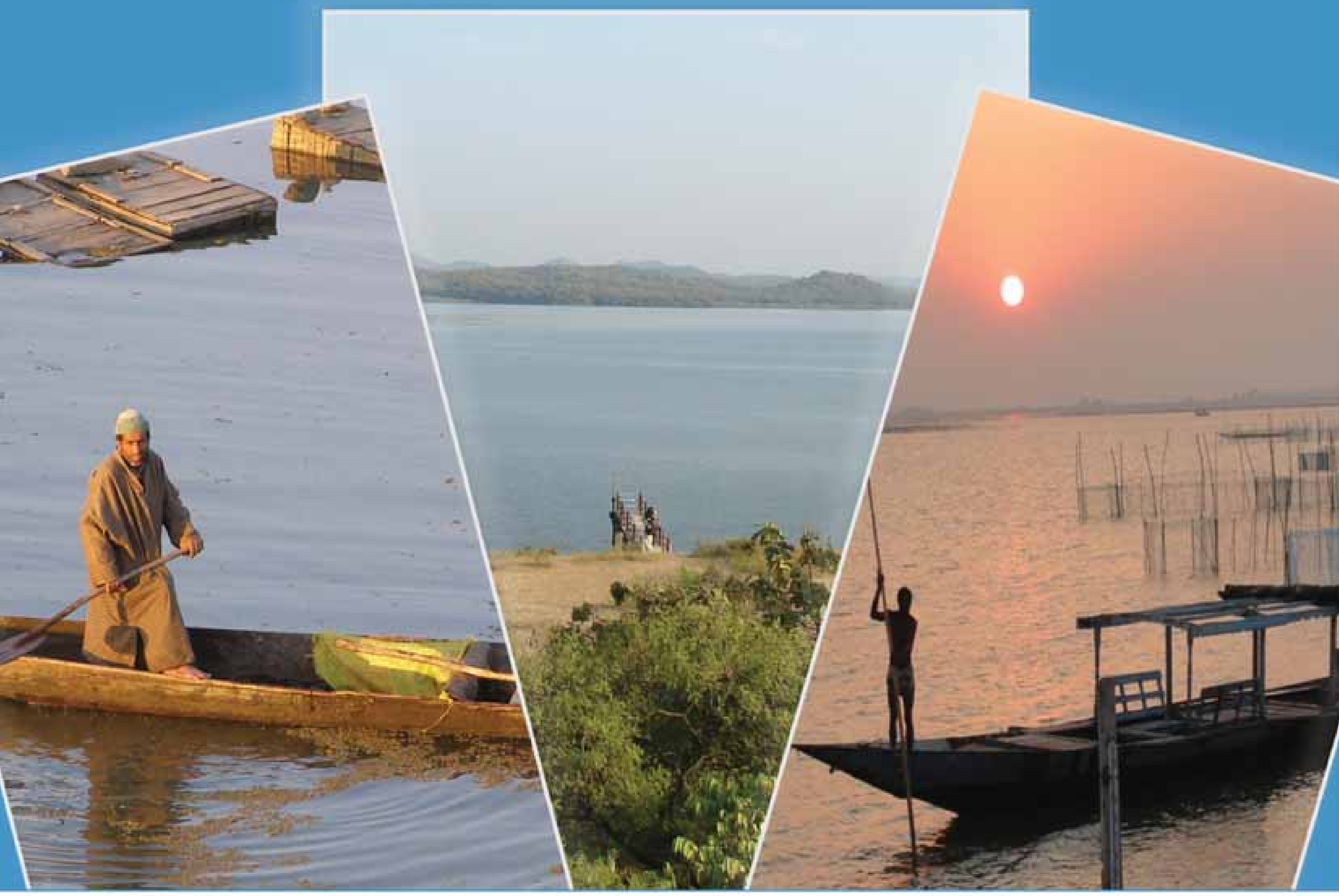
	Studies	Ecosystem Service	Forest type	Location	Economic value of ES	Methods
Provisioning Services						
1	Negi & Semwal, 2010	Fuelwood, fodder and manuring leaves	Oak and pine forests	Central Himalayan region, Uttarakhand	Oak forests: US$ 2958 (Rs. 139029) year-1 Pine forests: US$ 951 (Rs. 44688) year-1	Household surveys
2	Joshi & Negi, 2011	Fuelwood, fodder, wild edible fruits, minor timber, medicinal plants, natural fertilizer	Oak and pine forests	Western Himalayan region, Uttarakhand	Oak forests: Rs. 5676 person-1year-1 Pine forests: s. 4640 person-1year-1	Household surveys
3	Mahapatra & Tewari, 2005	NTFPs	Dry deciduous forests	Dhenkanal and Keonjhar districts, Eastern India	Coastal area: US$ 1016 (Rs. 36,584) ha-1 Inland area: US$ 1348 (Rs. Rs. 48,535) ha-1	Laying down sample plots and estimating per ha yield
4	Mahapatra & Tewari, 2005	Timber	Dry deciduous forests	Dhenkanal and Keonjhar districts, Eastern India	US$ 268 (Rs. 12,063) ha-1	Secondary data
5	Purushothaman *et al.*, 2000	Medicinal plants	Tropical deciduous forest	Jabalpur, Madhya Pradesh	US$ 18.02 billion year-1 (5% discount rate) and US$ 27.36 billion year-1 (10% discount rate)	Preliminary survey using quadrat method. Mean annual benefit per species x No. of medicinal plant species
6	Narendran *et al.*, 2001	NTFPs	All major vegetation types of peninsular India	Nilgiri Biosphere Reserve, South India	US $36 (Rs. 1211) ha-1 year-1	Surveys and market analysis
7	Murthy *et al.*, 2005	NTFPs	Moist deciduous, dry deciduous and semi-evergreen	Uttara Kannada district, Karnataka	Rs. 1159 ha-1year-1	Surveys and market analysis
8	Murthy *et al.*, 2005	Timber	Moist deciduous, dry deciduous and semi-evergreen	Uttara Kannada district, Karnataka	Rs. 535 ha-1	Secondary data from forest departments
9	Sarmah and Arunachalam, 2011	NTFPs	-	Changlang district, Arunachal Pradesh	Rs. 243 – Rs. 67938 year-1	Surveys and market analysis
10	Appasamy, 1993	NTFPs	-	Kadavakurichi Reserve Forest, Tamil Nadu	Rs. 1.9 million per year	Footpath Survey and market analysis

	Studies	Ecosystem Service	Forest type	Location	Economic value of ES	Methods
Regulating Services						
11	Singh, 2007	Carbon sequestration	Tropical and temperate forests	Indian Himalayan forest	US $ 85.91 million or Rs. 3.82 billion (at US$ 13 per ton carbon)	2 datasets; carbon value of forests from various sources and value of ES using estimates of Costanza et al were used.
12	Kadekodi and Ravindranath, 1997	Carbon sequestration	All Indian forests	Entire India	Rs. 96,203/ha	Potential for carbon sequestering through forestry in India was estimated and economic value for forests was derived.
13	Monograph 7, 2006	Prevention of soil erosion	All Indian forests	Entire India	Rs. 50244.21 million (2001-2002) and Rs. 47072.56 million (in 2003)	Resource value of soil loss approach, Replacement cost approach
14	Monograph 7, 2006	Augmentation of groundwater	All Indian forests	Entire India	Rs. 1325.08 million (2001) Rs. 1238.58 million (2003)	Water/hydrological balance methods
15	Monograph 7, 2006	Flood control	All Indian forests	Entire India	Rs. 118510.00 million (2001) and Rs. 111030.25 million (2003)	Flood avoidance benefits
16	Badola *et al.*, 2010	Carbon sequestration	Dry and moist deciduous forest	Corbett Tiger Reserve, Uttarakhand	US $63.6 million, with annual flow of US $65.0 ha-1 year-1	Replacement cost method
Supporting Services						
17	Kiran and Kaur, 2011	Nutrient retention	-	Halol range, Gujarat	Rs. 388.13 ha-1 (in 2009)	Replacement cost method
Cultural Services						
18	Badola *et al.*, 2010	Recreation	Dry and moist deciduous forest	Corbett Tiger Reserve, Uttarakhand	US $167,619 year-1	Travel cost method
19	Hadker *et al.*, 1997	Recreation	-	Borivli National Park, Maharashtra	Rs. 248 million year-1 (NPV= Rs. 1033 million)	Contingent Valuation Method
Holistic Studies						
20	Chopra, 1993	Fuelwood, fodder, forest products, soil conservation, nutrient recycling, tourism/ recreation	Tropical moist and dry deciduous forests	Entire India	US $4034 to $6662 ha-1	Market and non-market methods

	Studies	Ecosystem Service	Forest type	Location	Economic value of ES	Methods
21	Natural Resource Accounting in Goa, 2008	Timber, fuelwood, fodder, ecotourism, watershed benefits, carbon sink, biodiversity	Typical forests of the Western Ghats	Goa	Rs. 550 crores	Market price, substitution approach, productivity method, welfare method, avoidance cost and benefits transfer approach.
22	Verma, 2000	Salvage, Timber, Fuel wood, Fodder, Minor forest produce, Ecotourism, watershed, Microclimatic factors, Climatic factors, Carbon sink, biodiversity		Himachal Pradesh	Rs. 106664 crore	Valuation techniques and previous studies
23	Verma *et al.*2010	Forest cover (ha), Climate regulation, Disturbance regulation, Water regulation, water supply, Erosion control & sediment retention, Soil formation, Nutrient cycling, waste treatment, Biological control, Food production, Raw materials, Genetic resources, Recreation, Cultural	Tropical and temperate forest	Arunachal Pradesh, Himachal Pradesh, Meghalaya, Sikkim, Uttarakhand	AP – 5,39,234, HP – 1,14,320, Meghalaya – 1,35,157, Sikkim – 25,952, Uttarakhand – 1,94,461 (in million Rs)	Costanzia's Framework
24	Verma *et al.* 2010	Timber and Fuel wood, Carbon, NTFP, Fodder, Soil conservation, Water Augmentation, Flood prevention, Recreation, Biodiversity	Tropical and temperate forest	Arunachal Pradesh, Himachal Pradesh, Meghalaya, Sikkim, Uttarakhand	AP – 1782050.72, HP – 906176.20, Meghalaya – 462424.29, Sikkim – 54240.63, Uttarakhand – 642990.12 (in million Rs)	Green Accounting for Indian States (GIST)
25	Verma *et al.* 2010	Forest cover (ha), Timber logging, Fuel wood, Fodder, Grazing, Minor Forest Produce, Ecotourism, Watershed benefits, Microclimatic factors, Carbon stock, Carbon flux, Biodiversity, Employment generation	Tropical and temperate forest	Arunachal Pradesh, Himachal Pradesh, Meghalaya, Sikkim, Uttarakhand	AP – 4527293.76, HP – 959804.71, Meghalaya – 1134745.81, Sikkim – 217891.50, Uttarakhand – 1632649.93 (in million Rs)	Natural resource Accounting (NRA) project by Verma *et al.* (2006)
26	Verma *et al.* 2010	Timber, Fuel wood, NTFP, Ecotourism, carbon	Tropical and temperate forest	Arunachal Pradesh, Himachal Pradesh, Meghalaya, Sikkim, Uttarakhand	AP – 8282.41, HP – 8691.82, Meghalaya – 1300.81, Sikkim – 1943.31, Uttarakhand – 9591.69 (in million Rs)	Net Present Value (NPV)

	Studies	Ecosystem Service	Forest type	Location	Economic value of ES	Methods
27	Verma *et al.*, 2007					
	Climate regulation, Disturbance regulation, Water regulation and water supply, Erosion control, Soil formation, Nutrient cycling, Waste treatment, Biological control, food production, Raw materials, Genetic resource, Recreation, Cultural	Tropical and temperate forest	Uttarakhand	US $1150 / ha/ yr	Costanza et. al (1997)	
28	Verma *et al.*, 2007					
	Carbon sequestration	Temperate conifer, Temperate broad leaved, Tropical coniferous, Moist deciduous, dry deciduous and Sub tropical forests	Uttarakhand	US $ 85.93 million	Rana *et al.*, (1989) and Singh and Singh (1992)	
29	Verma *et al.*, 2007					
	Fuel wood, Fodder, Wood for agriculture, manuring leaves and Minor forest products	Oak and Pine forest	Uttarakhand	Oak forest – 139.0, Pine forest – 45.1 (000, Rs. / village/ yr)	Ralhan *et al.*, (1991) and Negi and Bhat (1993)	

3 Inland Wetland Ecosystems



Lead Authors
Ritesh Kumar, Wetlands International – South Asia, New Delhi
E J James, Karunya University, Coimbatore

Contents

1. Introduction

Ecosystems underpin human well-being, yet are under threat from a range of anthropogenic and non-anthropogenic drivers and pressures. The losses in natural capital have direct economic repercussions, which are unfortunately underestimated. Making the value of natural capital visible to economies and society creates an evidence base to pave the way for more targeted and cost-effective solutions.

The Economics of Ecosystems Services and Biodiversity (TEEB) study marks an important effort towards increasing visibility of the value of ecosystem services and biodiversity in policy and decision making processes. Its genesis is attributed to a 2007 meeting of environment ministers from the Governments of G8 + 5 countries, wherein it was agreed to "initiate the process of analysing the global economic benefit of biological diversity, the costs of loss of biodiversity and the failure to take protective measures versus the costs of effective conservation". The TEEB study led to delivery of a series of reports and assessments on the subject addressing the need of major user groups: national and local decision makers, business and wider public (TEEB 2010). While recognizing plurality of values, the study presents an approach that can help decision makers recognize, demonstrate and where appropriate, capture the values of ecosystems and biodiversity. The study also provides a range of case studies that emphasize the role of sound economics in supporting sound environmental protection, including explicit recognition, efficient allocation, and fair distribution of costs and benefits of sustainable use of natural resources.

Since the launch of TEEB – international study, several countries have initiated national studies focused on the economics of ecosystems and biodiversity, building on its framework and structure. The Ministry of Environment and Forests initiated TEEB-India Project in February 2011 focused on economics of ecosystems services of wealth of our national natural resources and biodiversity, with the following objectives:

- Synthesis of the latest ecological and economic knowledge to structure the evaluation of ecosystem services under different scenarios
- Assessing costs and benefits for conservation of ecosystem services for representative sites
- Providing policy specific recommendations at national , state and local levels to foster sustainable development and better conservation of ecosystems and biodiversity. This may include, but not limited to a detailed consideration of, subsidies and incentives, environmental liability, national income accounting, cost-benefit analysis, and methods for implementing instruments such as Payments for Ecosystem Services (PES)
- Identify information and tools for improved biodiversity-related business practice – from the perspective of managing risks, addressing opportunities, and measuring business impacts on ecosystems and biodiversity.
- Provide recommendations for raising public awareness of the contribution of ecosystem services and biodiversity towards human welfare, of an individual's impact on biodiversity and ecosystems, as well as identifying areas where individual action can make a positive difference.

A two-day consultation workshop on project implementation modalities was held on 15-16 September, 2011 at Indian Institute of Forest Management, Bhopal, in partnership with GIZ and DFID. Over 70 participants including leading academics drawn from the fields of environmental economics and ecology, representatives from the Ministry of Environment and Forests (MoEF), biodiversity boards, Planning Commission, Central Statistics Office, Forest Departments, research institutes and national and international NGOs attended the workshop. The following key recommendations emerged:

- Focus on forests, inland waters, and coastal and marine ecosystems in the first phase
- Commission scoping reports on the current state of knowledge on status and trends of ecosystems, drivers and pressures, ecosystem service values, way TEEB –India could contribute to conservation challenges and proposed methodology and implementation plan for the identified ecosystem type

- Not to limit the study on economic valuation but focus on full mix of economic approaches relevant to management of ecosystem services and thereby include economic instruments, role of regulation, governance, regulatory frameworks.

Following these recommendations, scoping studies were commissioned by the MoEF engaging experts to provide an analysis of the current state of knowledge on extent and state of ecosystems and their services, evidences of economic values, conservation challenges and the ways TEEB framework could contribute to the challenges.

The current report presents the findings of the scoping study done for inland waters. "Inland waters" are defined by the Convention on Biological Diversity as "aquatic-influenced environments located within land boundaries". Inland water systems can be fresh, saline or a mix of the two (brackishwater) and include lakes, rivers, ponds, streams, groundwater, springs, cave waters, floodplains, as well as bogs, marshes and swamps, which are traditionally grouped as inland wetlands. The CBD has adopted the Ramsar Convention's definition of "wetland." Under the text of the Convention (Article 1.1), wetlands are defined as:

> "Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres."

In line with the above, this report focuses on inland wetlands and address the following terms of reference:

- Overview of the extent and state of ecosystem in India
- Prominent examples of ecosystem types and services
- Key issues for conservation of ecosystem services and biodiversity
- Current state of art on valuation of ecosystem services and gaps
- The way TEEB assessment can contribute to the conservation challenges
- Proposed methodology and implementation plan for TEEB India
- Identification of challenges for the study, if any

The report builds on review of existing literature available in the form of peer reviewed journal articles, book chapters, technical reports, and conference papers. The findings are presented in four chapters. The first chapter provides the report background. The second chapter provides an overview of the status, trends and conservation needs of inland wetlands. The third chapter provides an overview of the state of art on valuation of ecosystem services of wetlands, and includes a discussion on the valuation studies done in inland wetlands of India. The fourth and the final chapter provides a proposal for implementation of TEEB – India project on inland wetlands and discusses the initiative's added value, methodology, study sites and challenges.

2. Inland wetland ecosystems in India: An overview of status, trends and conservation needs

2.1 Current Status

Distribution

Inland wetlands in India exhibit enormous diversity owing to wide variations in rainfall, hydrology, physiography, geomorphology and climate. The Himalayas are interspersed with a range of wetlands which include rivers and associated floodplain marshes, swamps, glaciated lakes, seasonal waterlogged areas and man-made wetlands which characteristically differ by the extremes of altitude, relief and climate experienced in the region (Trisal and Kumar, 2008). Of particular significance are the high altitude wetlands (located at an altitude of 3,000 m and above) which play an important role in regulating the hydrological regimes by capturing and retaining snow and ice melt and releasing water progressively. These wetlands are spread across Leh-Ladakh region in Jammu and Kashmir, parts of Uttaranchal, Himachal Pradesh, Sikkim and Assam. Pangong Tso, Chushul marshes, Hanle River marshes, Tso-morari, Tso-kar and parts of Mehao Sanctuary are some of the key high altitude wetlands of India, several of which act as stopover habitats of palearctic species migrating from the west, and east –south east Asia which later get spread over the entire Indian sub-continent constituting Central Asia Flyway (Trisal, 1996).These wetlands also serve as habitats for several cold water fishes (for example Schizothorax, Orienus, Schizothorichthys, Tor etc.). Sheshnag, Tarsar, Marsar and Gangbal are revered as religious sites.

The alluvial plains of River Ganges and Brahmaputra forming a crescent like lowland between the Deccan peninsula and Himalayas have extensive riverine formations as river floodplains and oxbow lakes, variously known as mauns, beels , chaurs, jheels and pats. Most of the Himalayan Rivers after traversing higher gradient of foothills suddenly debauch to the flat and tectonically depressed lands which become instrumental in formation of loop like or serpentine oxbow lakes present in the entire plains of Ganga and Bramhaputra and their tributaries. Kusheshwar sthan, Kabar taal, Simri-Bakhtiarpur and Goga Beel of North Bihar are representative chaur areas which play an important role in supporting local livelihoods through fisheries and economically important macrovegetation as *Euryle ferox* and *Nelumbo*. The East Kolkata Wetlands on the eastern fringes of Kolkata City were originally backwater swamps of Bidhyadhuree River, which were cutoff due to deltaic processes and finally engineered to receive the entire wastewater of Kolkata. These now represent the world's largest assemblage of sewage fed fisheries and play an important role in food security of Kolkata City.

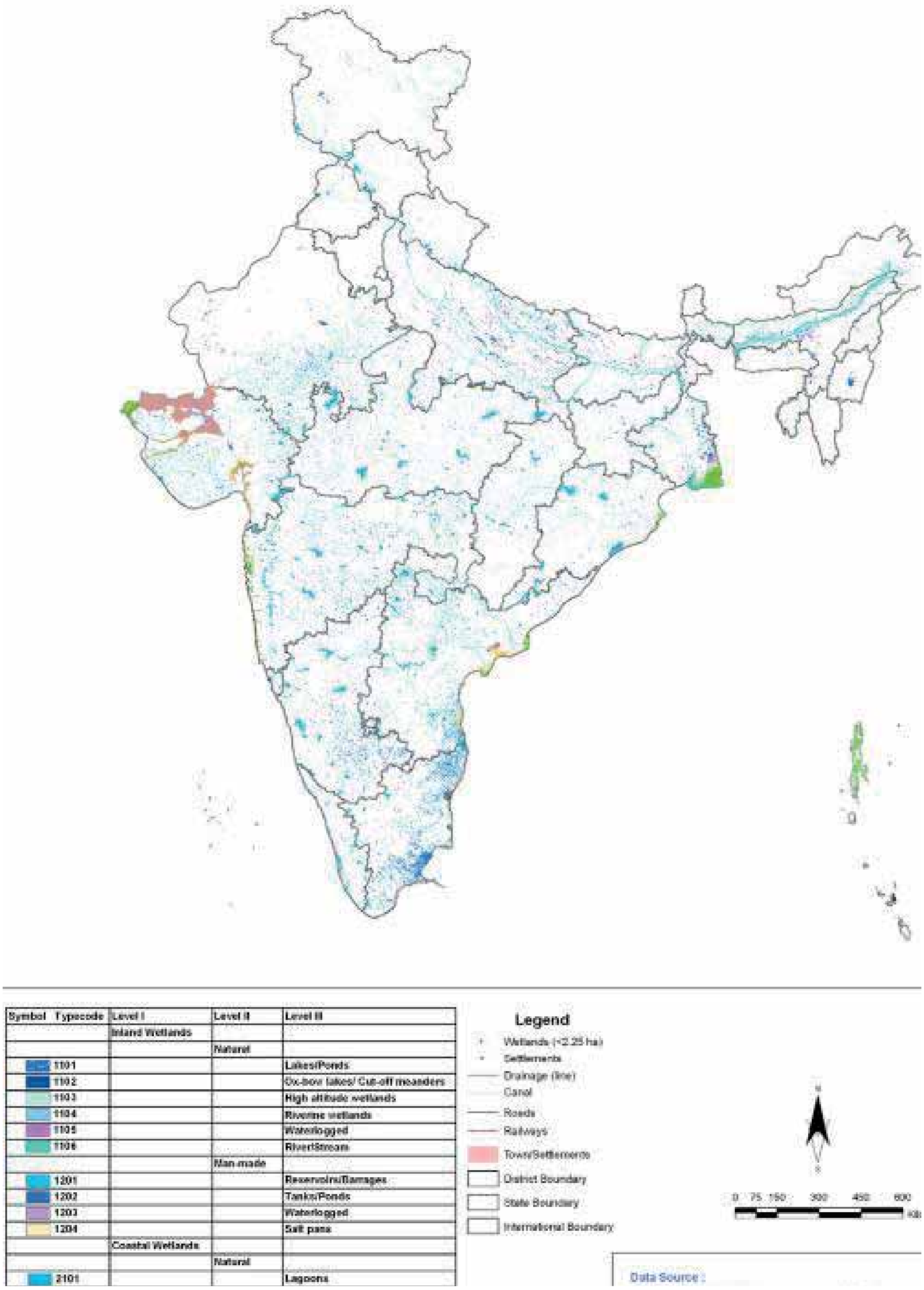
The southern flank of Gangetic plains contains some important riverine habitats, such as Chambal which provides refuge for several threathened species of wildlife, such as Gharial (*Gavialis gangeticus*). Also situated on the rim of Gangetic plains within the floodplains of River Gambhir is the Keoladeo Ghana National Park, Bharatpur, once famous as the primary wintering site of Siberian White Crane (*Grus leucogeranus*). The swamps of forested wetlands of Bramhaputra valley contain some of the most important wildlife habitats, for example Kaziranga National Park which is home to One-horned Rhinoceros (*Rhinoceros unicornis*). Similarly, the floodplains of Manipur River include the habitat of globally rare and endangered Brow-antlered deer (*Rucervus eldii*) within Keibul Lamjao National Park in Loktak Lake.

The arid zone, spanning Rajasthan and Gujarat, including the peninsular regions of Saurashtra and Kutch is characterised by vast saline flats complemented by monsoon fed freshwater lakes and reservoirs. The Rann of Kutch has mostly halomorphic soils which remain dry for most parts of the year forming white crusts of salt on the surface. The mudfalts of the Rann include the mass nesting areas of Greater Flamingo (*Phoenicopterus roseus*), giving it the name 'Flamingo City'. The arid region also has several salt lakes (Sambhar, Pachpadra, Deedwana and Lukransar), regimes of which are determined by monsoonal runoff and sparse growth of halophytic vegetation (species of *Suaeda, Salsola, Salicornia* etc.). Although these wetlands have relatively low biological diversity, several of these attract large numbers of flamingos. Areas of rural Gujarat are dotted with numerous natural, semi-natural and man-made ponds of varied shapes, size and depth. These areas also provide breeding site for the endangered Indian Sarus Crane. Nal Sarovar, one of the largest lakes of the country in Surendranagar and Ahmedabad district supports large number of waterfowl and aquatic plants.

The Peninsular Deccan region has few natural wetlands and is mostly studded with manmade tanks made for providing water for various human needs, besides serving as nesting, feeding, and breeding sites for a large variety of bird species (eg. Varthur, Rachenahalli and Amruthalli Lakes in Bangalore, and Sasthamkota in Kerala). The Bhoj Wetlands for example, are the principal source of water for the city of Bhopal. The temple tanks of Tamil Nadu are a unique cascading rainwater harvesting system.

The narrow plains of the east and the west coast, apart from harbouring a rich diversity of coastal wetlands as estuaries, backwaters, mangroves, coral reefs has lake and lagoons which depend both on riverine and marine exchange. Most of these are characterized by a barrier connected at least intermittently to the sea by one or more restricted inlets and usually oriented parallel to the shore. Chilika, a brackishwater lagoon is a hotspot of biodiversity and harbours several endangered and endemic species, including Irrawaddy Dolphin (*Orcaella brevirostris*). The diverse and dynamic assemblage of fish, invertebrate and crustacean species found in the wetland provide the basis of a rich fishery which supports over 0.2 million local fishers. Kolleru Lake, located within the Godavari and Krishna Deltas acts as flood balancing system between the two deltas and was once famous for breeding colonies of spot-billed or Grey Pelican which represented the highest known population of this species in India. Pulicat and Point Calimere and Asthamudi are other significant lagoon systems on the Indian coastline.

Map 3.1. Map of Wetlands of India (Source : SAC, 2011)



Extent

Attempts to assess the overall extent of wetlands in the country have been made since the 1960s. A National Inventory of Wetlands, by the title of All-India Wetland Survey was initiated by the Government of India in the late 60s. In early 80s, a working group was established by the Department of Environment which further circulated an enlarged questionnaire for information on wetlands to improve the database. An estimate of 3.9 million ha was recorded in the survey. The Asian Wetland Inventory reported the total wetland area in India to be 58.3 million ha, which included 40.9 m ha under paddy cultivation (Scott, 1989). A review of efforts made to inventorize wetlands using non-remote sensing based approaches is presented in Gopal and Sah (1995).

Use of remote sensing and GIS techniques for assessing national wetland extent began in the nineties. The SAC mapped the wetlands using a mix of 1: 250,000 and 1:50,000 resolutions using data of 1992-93. The overall wetland extent was assessed to be 8.26 million ha of which 3.55 million were classified as inland (SAC, 1998).

The UNDP sponsored project on ‘Inland Wetlands of India – Conservation Priorities’ marked the second major remote sensing based inventory of wetlands in India (Vijayan *et al.* 2004). The project mapped wetlands for 72 districts of 10 states using 23.5 m resolution data of IRS LISS III mostly of 2001.

Further, the assessment also included conservation significance by collecting and collating information on endemic aquatic plants, fishes, freshwater turtles and wetland birds. Finally, the study prioritized the 655 wetlands for conservation using criterions related to biodiversity and socio-economics, and recommended 199 wetlands to be declared as Ramsar Sites, to be brought into the ambit of wise use. It also recommended that the remaining sites be classified as wetlands of national importance and all sites included into a national network of wetlands.

Concerned with gaps in information and lack of consistent methodology, the Ministry of Environment and Forests initiated a nation-wide wetland mapping project entitled ‘National Wetland Inventory and Assessment’ with the Space Application Centre (SAC) during 2007-2011. Overall 19 wetland type classifications were used (Map 3.1). Small wetlands of below 2.25 ha were mapped as point features. RESOURCESAT I LISS III data of 2006 – 07 at 1: 50,000 scale (with 23.5 m resolution) for two periods (March to June corresponding to pre-monsoon and November to December for post monsoon) was used for defining extent of wetlands. The study estimated the extent of wetlands in the country to be 115.26 million ha of which inland wetlands accounted for 69.22% (10.56 million ha). The high altitude wetlands comprised 126,249 ha of areal extent. Statewise area under inland wetlands is presented in Fig 3.1, whereas Fig 3.2 provides estimates as per inland wetland categories.

Figure 3.1. State-wise area under inland wetlands (SAC, 2011)

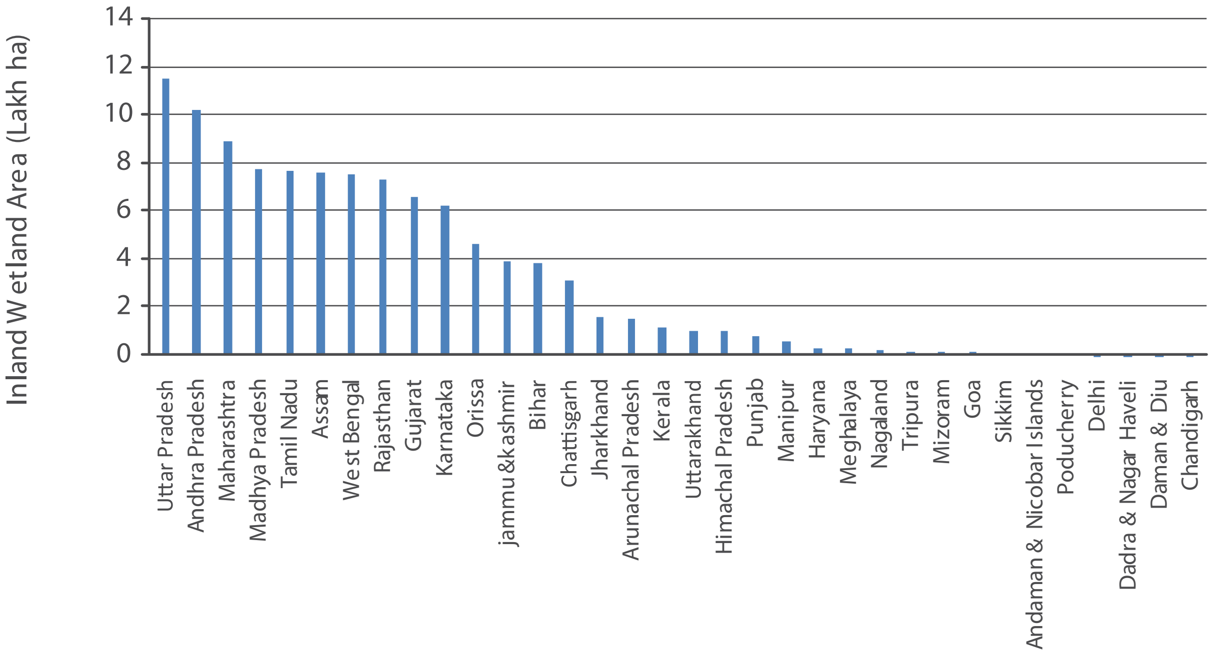
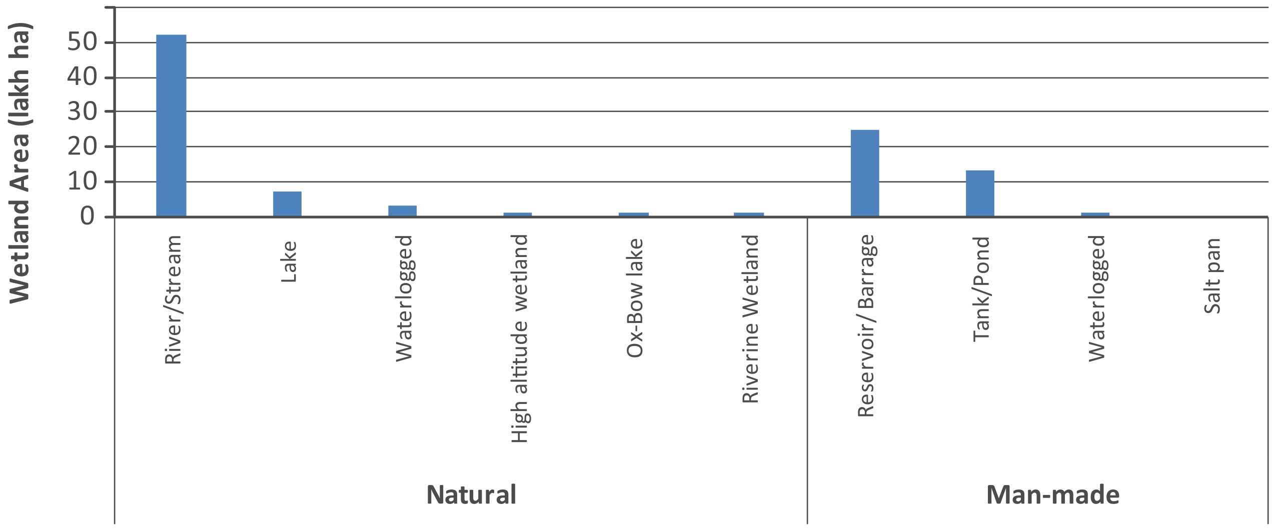


Figure 3.2. Area under various inland wetland types (SAC, 2011)



Biodiversity

Inland wetlands support a range of floral and faunal diversity. The information presented in this section is primarily built on the report of the Thematic Group on Natural Aquatic Ecosystems of India formulated by a team led by Zoological Survey of India as a part of the National Biodiversity Strategy and Action Plan (Venkatraman, 2003), information on biodiversity presented in the inland wetlands inventory (Vijayan *et al.* 2004), records of Zoological Survey of India, and reports of the Asian Waterbird Census. All of these assessments have invariably stressed the need for a systematic collation and interpretation of biodiversity information related to wetland systems. The floral diversity supported by inland wetlands range from unicellular algae through bryophytes, mosses and ferns to woody angiosperms. The total number of aquatic species in the country is known to exceed 1,200 species, reported to be an underestimate as it builds on information from few states and taxonomic groups. Vijayan *et al.* (2004) have presented a list of 730 species of wetland angiosperms of which 114 are endemic to the country.

The faunal diversity supported by inland wetlands is equally rich, with some specific fully using the aquatic habitat for the entire lifecycle (eg. fish, dolphins, otters etc.), whereas some using it partially or even obligate (swamp deer, sangai, hog deer, fishing cat, rhinoceros, elephant, wild buffalo, etc.). The ZSI has assessed the faunal diversity of Indian wetlands at 17,853 (19.9%) of 89,451 species occurring in India (Alfred *et al.* 1998; Alfred and Nandi, 2000). These freshwater faunal elements are dominated by insects (about 5,000 species), mollusks and fishes (each representing about 2,000 species). The estimated figures are expected to increase many times especially of micro invertebrates and parasitic groups, if these groups are extensively explored from all over Indian eco-regions.

There are several wetlands which are hotspots of diversity, for example Keoladeo Ghana National Park which is a habitat for 21 mammal species including six ungulates (*Antelope cervicapra, Axis axis, Cervus unicolor, C. porcinus, Boselaphus tragocamelus* and *Sus scrofa*). The wetlands in Jaldapara Wildlife Sanctuary in West Bengal are primarily protected for the One-horned Rhinoceros (*Rhinoceros unicornis*). Other large mammals include the Tiger (*Panthera tigris*), Indian Elephant (*Elephas maximus*), Swamp Deer (*Cervus duvaucelli*) and possibly the rare Pygmy Hog (*Sus salvinus*). The wetlands of Manas Wildlife Sanctuary in Assam also support an extremely varied mammalian fauna including the Indian Elephant and One-horned Rhinoceros. The swamps of Keibul Lamjao National Park are famous as the last refuge of the Manipur Brow-antlered Deer (*Rucervus eldii*) locally known as "Sangai". The swamp deer in Dudhwa Tiger Reserve and its migration into the wetlands demonstrate the role these ecosystems play in the lifecycle of mammals of Terai region.

As per assessments carried by Indian Council for Agricultural Research (ICAR), Indian waters provide habitat for 877 inland and 113 brackishwater fish species (ICAR 2011). However, no estimate has been provided for the numbers that use inland wetlands as habitats. Vijayan *et al.* (2004) have listed 803 species of fishes from the inland wetlands of which 102 are classified into IUCN's threatened category (14 critical, 39 endangered and 49 vulnerable). The state of Kerala is reported to have the maximum number of threatened fish species followed by Assam, Tamil Nadu, Uttar Pradesh and West Bengal. A special mention is made of the aquatic mammal, the Ganges dolphin (*Platanista gangetica*) which is now an endangered species. Studies of large Indian reservoirs by Sugunan (1995) have indicated presence of 60 species of which 40 substantially contributed to commercial fisheries.

Since the establishment of Asian Waterbird Census (AWC) in 1987, waterbirds in 3,296 sites have been counted till 2007 which included 18 Ramsar Sites, 4 World Heritage, 1 Man and Biosphere Reserve, 126 Important Bird Areas and 112 Protected Areas (Li *et al.* 2009). A total of 171 waterbird, 25 raptor and nine kingfisher species were recorded. Over 100 sites supported more than 20,000 waterbirds during a count and 458 sites supported over 1% of the known biogeographic population of atleast one species of waterbird. The AWC assessment also identified 13 sites with records of over 100,000 waterbird numbers during a count. Under the Inland Wetlands of India: Conservation Priorities Project undertaken of SACON, the research team recorded 314 bird species around 591 surveyed wetlands. Of this, 231 species were reported to be either fully or partially dependant on wetlands (Vijayan *et al.* 2004).

India ranks high in species endemism with 28,145 faunal species being endemic (Alfred, 1998). India ranks tenth in birds, fifth in reptiles and seventh in amphibians with 69, 156 and 110 endemic species respectively. In aquatic system highest degree of endemism is found in amphibia (61.24%) freshwater porifera (41.93 %) and freshwater molluscs (41.8%) (Alfred, 2006). There are two endemic fish families in India i.e. *Parapsylorhynchidae* and *Horaichthydae*. A total of 223 fish species are endemic representing 8.75% of the fish species known to India and 127 monotypic genera representing 13.10% of the Indian genera of fishes (Barman, 1998). High level of fish endemism is witnessed in Western ghat region. In mammals a single species Herpestes palustris, has been reported to be endemic from salt lake swamp. About seven avian species including the Andaman Teal, Andaman Crake etc. are endemic to Indian wetlands (Kumar *et al.* 2005). Endemic habitats are unique, and with changing climate, require exclusive management to conserve the biodiversity living therein.

Ecosystem Services

The rich diversity within inland wetland systems and associated ecosystem processes give rise to a range of services that form the basis of lives and livelihoods of dependent communities. Two of the most important inland wetland ecosystem service affecting human well-being involve fish supply and water availability. The principal supply of renewable freshwater comes from an array of inland wetlands. Groundwater often recharged through wetlands plays an important role in water supply, especially for agriculture (nearly 60% of irrigation in India is sourced from groundwater). Inland fisheries production stood at 3.5 million tonnes in 2004-05, contributing 1.04% of national Gross Domestic Product and 5.3% of agriculture and allied activities. Most importantly, fisheries are the primary sources of animal protein for a large population.

No efforts have been made to inventorize and assess ecosystem services of inland wetlands. Site specific examples of select ecosystem services are provided in Table 3.1 below.

Table 3.1. Examples of ecosystem services from Indian inland wetlands

Ecosystem services type	Description	Examples
Provisioning		
Food	Production of fish, wild game, fruits, gains	East Kolkata Wetlands (West Bengal) produce 15,000 MT of fish annually. The combination of agriculture and aquaculture practiced in the wetlands provide livelihood support to large, economically underprivileged, peri-urban population of 20,000 households (Wetlands International, 2010)

Freshwater	Storage and retention of water, provision of water for irrigation and drinking	Harike wetland (Punjab) provide irrigation and drinking water to parts of southern Punjab and adjoining Rajasthan through 456 km long canals carrying approximately 26 m acre feet of water (Ladhar *et al.* 1994)
Fiber and fuel	Production of timber, fuelwood, peat, fodder	Fuelwood, fodder and construction material sourced from Kabartal (Bihar) support livelihoods of 67% households of 21 villages living around the wetland (Ambastha *et al.* 2007)
Genetic materials	Medicines ,genes for resistance to plant pathogen, ornamental species	17 plant species found in Loktak Lake (Manipur) have been found to have medicinal properties and used by communities for various diseases (Trisal and Manihar 2004)
Regulating		
Hydrological regimes	Ground water recharge and discharge, storage of water for agriculture or industry	Recharge of aquifers by Yamuna floodplains plays an important role in water supply for the city of Delhi (Trisal *et al.* 2008)
Pollution control and detoxification	Retention, recovery and removal of excess nutrients and pollutants	Phumdi in Loktak Lake store a significant proportion of nutrients received from highly polluted Manipur River thereby regulating water quality of the wetland (Trisal and Manihar 2004)
Natural hazards	Flood control, storm protection	Deepor Beel wetland water holding capacity extends upto 40.1km^2 during flooding and prevent nearby areas from submerging (Gogoi, 2007)
Cultural		
Spiritual and inspirational	Personal feelings and well being, religious significance	Khecheopalri Lake (Sikkim) is revered as 'wish fulfilling lake' and considered most sacred by Sikkemese people (Maharana *et al.* 2000)
Recreational	Tourism and recreational activities	Lake Chilika (Orissa) is annually visited by 0.45 million tourists creating an economy worth Rs. 2,300 million for various sectors (WISA, 2011)

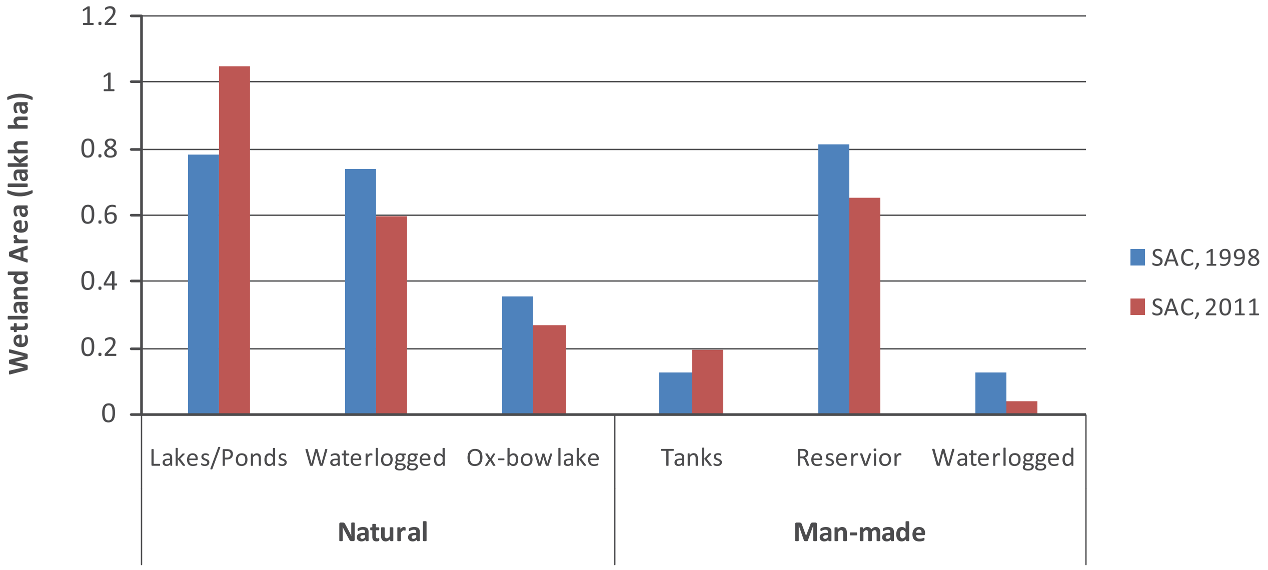
2.2 Trends

Lack of comprehensive and systematic baselines and periodic assessments on inland wetlands render defining trends difficult and open to interpretations. The two remote sensing imageries based inventories carried by Space Application Center for 1992-93 and 2007 have comparable resolutions for 85 districts and 6 inland wetland types. The total wetland area for the 6 types was observed to have declined by 5% in the said districts. An overall decline in 46 of the 86 districts can be observed. While the area under lakes, ponds and tanks were reported to have increased, a decline in area waterlogged, reservoirs and ox-bow lakes can be seen (Fig 2.3).

Specific categories of wetlands are also assessed by the ministries of water resources, land resources and fisheries.

Assessment of site level changes in wetland extent has also been the focus of several land use / land cover change studies. During the course of current study, 11 studies pertaining to inland wetlands located within 10 states were analysed. The period of reference ranges from 13 years (Wetlands of

Figure 3.3: Changes in inland wetland areas in select district



Sirohi District, Rajasthan) to 96 years (for Wular Lake, Kashmir). The rates of loss have been found to vary from 5% to 90% (in the case of Rudrasagar Lake, Tripura). On an average, the studies indicated 39% loss in area over an average period of 27 years. A summary of the studies is presented in Table 2.2.

While the assessments related to extent of wetlands give some indication of trends, it is further difficult to get a national overview on trends related to biodiversity and ecosystem services. However, there are ample site specific evidences for nearly all wetland types and geographical regions indicating human imprint in degradation and loss of wetlands in the country. Some of these are discussed in the following section.

Table 3.2. Changes in area for select inland wetlands

S. No	Site and Study reference	Baseline Assessment		Current Assessment		Methodology
		Area (ha)	Year	Area (ha)	Year	
1	Deepor Beel, Assam (Deka *et al.* 2011)	711.70	1991	421.30	2010	Mapping has been carried out using LANDSAT TM data for the year 1991, 2001 and 2010 is used to delineate the change
2	Wetlands of Sirohi District, Rajasthan (Navatha *et al.* 2011)	11,961.00	1992	11,307.00	2005	Landsat TM data of October, 1992, IRS-P6 LISS-III data of October 2005 and IRS-P6 AWiFS data of January, February, March, April and May months (2005) have been used in the study. Scale used: 1:50,000
3	Loktak wetland complex, Manipur (WISA, 2011)	34,080.00	1970	22,802.00	2009	Topographical maps of year 1970 by SOI used for base map. Mapping has been carried out using Quick bird imagery for year 2009
4	Wetlands of Bangalore, Karnataka (Ramachandra and Kumar, 2008)	2,324.00	1973	1,005.00	2007	Creation of base layers from the SOI topo sheets of scale 1:250 000 and 1:50 000. RS data used for the study are: Landsat MSS data of 1973 MODIS 7 bands product of 2002 and 2007 IRS LISS-3 (23.5 m) data of 2006
5	Harike Lake, Punjab (Sarkar and Jain, 2008)	10,031.00	1990	7,108.00	2003	Wetland area mapping has been carried out using multi date IRS Satellite data at 1:25000 scale for the year 1990, 1999 and 2003

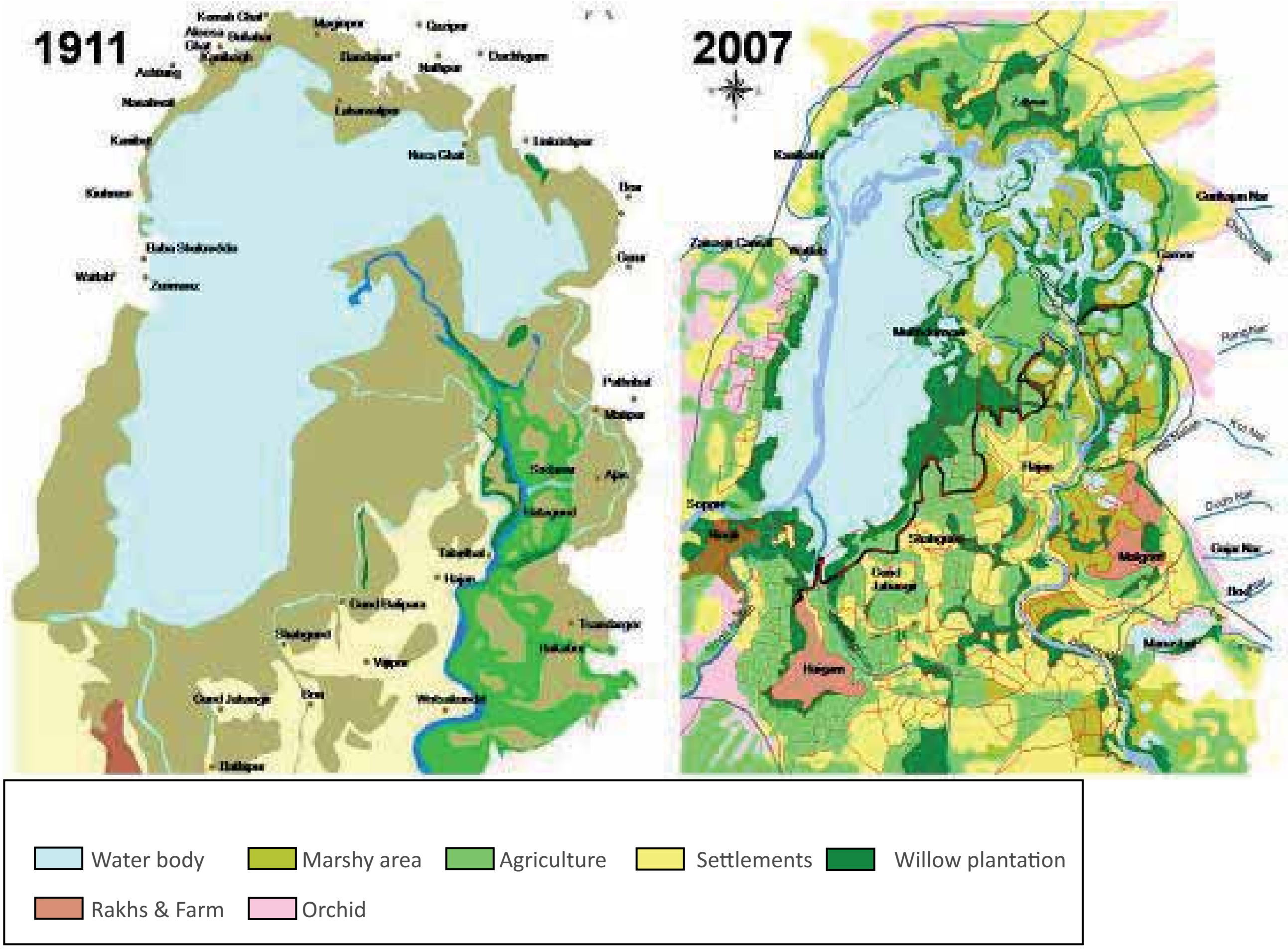
S. No	Site and Study reference	Baseline Assessment		Current Assessment		Methodology
		Area (ha)	Year	Area (ha)	Year	
6	Wetlands of 5 district of UP (Bahraich, Barabanki, Hardoi, Rae Bareli, Sitapur), Uttar Pradesh (Vargeese *et al.* 2008)	8,32,637.08	1972	2,10,205.65	2004	Wetland area mapping has been carried out using topo sheet at 1:25000. Advanced Wide Field sensor (AwiFS) image of IRS P-6 Resourcesat-1 has been used to delineate the pre-monsoon extent of wetlands
7	East Kolkata Wetlands , West Bengal (WISA,2008)	6,117.91	1986	5,852.14	2003	Interpretation of Topo sheets of SOI (1959-60) and RSI (2002)
8	Ansupa lake, Orissa (Pattanaik and Reddy, 2007)	317.00	1973	176.00	2004	Topo sheet (SOI) at 1:50000 scale used as base map. Landsat multi-spectral scanner (MSS)of year 1973 and IRS P-6 Resourcesat-1 and LISS III of year 2008 has been used to delineate the change
9	Wular Lake, Jammu and Kashmir (WISA, 2007)	15,774.00	1911	8,671.00	2007	Data of 1911 available through SOI toposheets. Data of 2007 based on remote sensing imageries.
10	Rudrasagar, Tripura (WISA, 2005)	1,000.00	1950	100.00	2005	Historical records
11	Kabartaal, Bihar (Ghosh *et al.* 2004)	6,786.00	1984		2002	Satellite imageries of IRS-WiFS Sensor (1984and2002) processed on ERDAS-IMAGINE Version 8.3

2.3 Key issues for conservation of inland wetland ecosystem services and biodiversity

Fragmentation of hydrological regimes: Wetlands are adapted to their hydrological regimes. Water regimes set the template which structure their biodiversity and ecosystem services. Fragmentation of hydrological regimes through water regulating structures has a high impact on the wetland system through reduced water availability, loss of connectivity with biodiversity habitats, impeded nutrient exchange and other processes which significantly enhance their degradation. Construction of flood embankments and roads around Wular Lake is one of the key factors leading to loss of marshes connected to the lake reducing its ability to regulate water regimes of River Jhelum (Map 3.2). Formation of reservoirs is known to affect the indigenous fish stocks of the anadromous hilsa, the catadromous eels, and freshwater prawn of major river systems. Construction of Ithai Barrage downstream of Loktak Lake to divert water for hydropower generation has converted a natural floodplain lake with fluctuating water levels into a reservoir, critically affecting the habitat of Manipur brow antlered deer and near complete obstruction of migratory pathways of fishes from Chindwin – Irrawaddy system.

Catchment degradation: The water holding capacity of wetlands plays a crucial role in determining its ability to regulate flow regimes, cycle nutrients and support biodiversity. Degradation of wetland catchments have a direct impact on water holding capacity and overall water regimes accentuating degradation. Bathymetric surveys for Harike Lake (Punjab) carried out in 2010 have indicated a loss of 86% of water holding capacity since 1954 due to catchment degradation. This has led to shrinkage in overall wetland area and supported proliferation of invasive species *Eicchornia*. Surajkund and Badhkal

Map 3.2. Landuse change in Wular Lake and associated marshes



Lakes, tourists hotspots in the vicinity of Delhi have run dry on account of excessive mining in the catchments, which prevents inflow of rainwater, and recharge of groundwater critical to maintenance of hydrological regimes of these wetlands.

Pollution: Wetlands, particularly in urban areas are often used as landfills and waste dumping grounds. This affects their water quality, promotes encroachments and reduces the overall aesthetics, besides creating health hazards for dependent communities. The source of pollution need not be the immediate surroundings but could also be upstream reaches in case of connected riverine systems. Most of the Gagentic floodplains wetlands are in advanced state of eutrophication due to discharge of untreated sewage and sewerage as well as runoff from nutrient rich agricultural fields. A Pollution Audit of Indian waterbodies carried by Comptroller and Auditor General of India in 2010 (covering 140 projects across 24 river stretches and 22 lakes in 116 blocks across 25 states of India) indicated high levels of organic pollution, low oxygen levels for aquatic organisms, and high contamination with protozoa and viruses of faecal origin. With only one tenth of waste water generated in the country treated, the rest invariably finds its way to wetlands.

Invasive species: Most of the inland wetlands have been invaded by exotic species which have acquired nuisance proportions threatening the very existence of many of the habitats, and have considerably influenced the native biota and total biodiversity. The list is topped by the water hyacinth, which was introduced into India about a century ago (Gopal, 1987) and occurs now throughout India except in the cold regions of high altitudes and Jammu and Kashmir. The other major species that have gradually spread over large parts of the country are *Salvinia molesta* , *Ipomoea carnea* spp. and *Alternanthera philoxeroides*. Yet another exotic, *Fistulosa*, introduced as a terrestrial species, has invaded wetlands all over India, and often forms dense stands.

Over 300 exotic species have been brought to India for experimental aquaculture, sport fishing, mosquito control and aquarium keeping of which several have established in Indian water bodies. Devastating impacts have been observed mostly in case of Tilapia, (*Oreochromis mossambicus*), which has invaded the fresh and brackish water bodies replacing the native fish fauna as in case of Bharathapuzha, the longest river in Kerala (Kumar, 2000). Similarly introduction of *Cyprinus carpio* in Dal Lake and Loktak Lake has impacted the population of indigenous *Schizothorax* sp. and *Osteobrama belangeri* respectively. Introduction of silver carp has depleted the native population of Catla and Mahaseer in Govind Sagar (Menon, 1979; Molur and Walker, 1998).

Over-harvesting of resources: Wetlands in India have high direct and indirect dependence, often leading to over-harvesting of resources. The resources of economic importance, flora or fauna are utilised to an extent of posing threat to the sustainable use of the species and the population depending on it in the food chain. Often the limit of sustainable yield for a particular wetland is not known. Wetland biodiversity is also put to stress by loss of by-catch.

Awareness and participation: There is limited awareness on wetland ecosystem services and biodiversity on an overall. Wetlands are multiple use systems with role of a range of stakeholders in their management. However, most of the site level institutions mandated for management of wetlands include only government institutions. Management approaches also do not fully internalize informal and traditional community led resource management practices, sometimes leading to conflicts. There are limited incentives for local resource stewardships. Limited participation reduces management effectiveness. Mainstreaming the values of natural capital can help in sustainable management of wetland system.

2.4 Management efforts and gaps

Policy and regulatory frameworks

India does not have a separate wetlands policy. Key policy directions for wetland management are contained in the National Environment Policy (2006), which recommends adoption of integrated approaches, specifically river basin management and site specific prudent use as guiding actions.

The regulatory framework for conservation of wetlands is defined by the Wetland (Conservation and Management), 2010 notified under The Environment (Protection) Act, 1986. 'Environment' as defined in Section 2 of the Environment (Protection) Act included water, air and land and the interrelationship which exists between water, air and land and human beings and other living creatures, plants and micro-organisms and property. The Wetland Rules of 2012 is the first major national framework for regulating detrimental activities related in wetlands and their catchments. Its coverage of the rules include Ramsar sites, high altitude wetland sites with area greater than 5 ha, sites or complexes below 2,500 m with an area of 500 ha and above, those designated as World Heritage Sites, and those specifically included under the provisions of the rules. A Wetland Regulatory Authority has been constituted for the purpose of enforcement of the rules, to determine the proposals sent by the state governments and set thresholds for activities to be regulated, amongst various functions. The state governments have been entrusted with the task of identification of wetlands to be included under the ambit of the act. The rules, however, exclude river channels, paddy fields and coastal wetlands (already covered under the Coastal Regulation Zone notification, most recently updated in 2011)

India is a signatory to the Ramsar Convention on Wetlands. As a contracting party, India is committed to the Convention's principles of ensuring maintenance of ecological character of Wetlands of International Importance (Ramsar Sites) and to plan for "wise use" of all wetlands in her territory. As on date, India has designated 25 Ramsar Sites. Similarly, as a contracting party to the Convention on Biological Diversity (CBD), India is committed to supporting implementation of the Convention's Strategic Plan 2011-2020, which includes several direct and indirect references to wetlands, particularly their role in maintenance of hydrological regimes. Central Asian Flyway Action Plan under the Convention on Migratory Species requires conservation of migratory birds and their habitats prominently including wetlands.

State governments have also enacted rules for conservation and management of wetlands within their jurisdiction. The Government of Manipur notified the Manipur Loktak Lake (Protection) Act, 2006 and Manipur Loktak Lake (Protection) Rules, 2008 which define a core zone and buffer zone, and stipulate specific activities that can be permitted within these designated areas. Similarly, the East Kolkata Wetlands (Conservation and Management) Act, 2006 restricts changes in land uses, diminution of wetland area, change in ecological character and establishment of East Kolkata Wetland Management Authority for enforcement of the Act. The government of Orissa is in advanced stages of introducing a bill in its legislative assembly which would empower the authority to regulate detrimental fishing, amongst various other stipulations. The Orissa Marine Fisheries Regulation Act (OMFRA, 1982) bans several forms of fishing in Chilika. In Kerala, the Conservation of Paddy Land and Wetland Act, 2008, is one of the few examples wherein rice paddies are considered as wetlands and their conversion banned. The Guwahati Water Bodies (Preservation and Conservation) Bill of 2008 empowers the government to preserve wetlands and acquire peripheral areas for protection of waterbodies.

Programmes

Recognizing their ecological and socioeconomic importance, a range of wetland research, management and conservation policies and programs have been developed by the national and state governments and are under implementation, the flagship being National Wetland Conservation Programme of the MoEF, under which 115 wetlands have been identified as of national priority. Under this program, the national government provides financial support for implementing management plans which includes support to components on catchment conservation, management of hydrological regimes, biodiversity conservation, sustainable livelihoods of wetland dependent communities, communication and awareness generation and institutional development. Since the seventh plan period (1985-1990), investments under the NWCP have grown from US$ 0.6 million to over US$ 20 million at present (per five year planning cycle), with the scope covering all states of the country and all major wetland types. Efforts have been made in the program to build capacity of wetland managers, and create awareness amongst stakeholders on the values and functions of wetland ecosystems. Similarly 52 lakes and 38 mangroves and coral reefs areas have been identified for priority conservation under the National Lakes Conservation Plan and National Programme on Mangroves and Coral Reefs. India has also designated 25 wetlands as Wetlands of International Importance or Ramsar Sites under the Convention on Wetlands underlining its commitment to ensure wise use of these ecosystems. The ecological restoration of Chilika Lake which led to removal of the site from the Montreaux Record (a list of sites with negative changes maintained by Ramsar Convention) and significant recovery of biodiversity and livelihoods was conferred the Ramsar Award in 2002, and recognized as a model initiative.

Apart from the Ministry of Environment and Forests, there are some state government led wetland restoration programmes. The Planning Commission has provided financial assistance to restoration of Loktak Lake, being implemented by the Loktak Development Authority. Non-government organizations as Wetlands International South Asia (WISA), World Wide Fund for Nature - India (WWF), Bombay Natural History Society (BNHS) and Salim Ali Center for Ornithology (SACON) implement programmes related to wetland management planning, waterbird monitoring, community participation, research, capacity building and awareness generation.

Gaps and Challenges

- **Insufficient investment into wetland conservation:** The national wetland inventory identified existence of over 0.18 million inland wetlands in the country and over 0.56 million wetlands of less than 2.25 ha area. The programmes of the Ministry and other agencies cover a fraction of these wetlands. Thus while some large wetlands and those with high biodiversity value have received focus of funding, there is a large section which remained unattended to. The overall size of the funds available through the national wetlands conservation programme is limited. On the other hand, development sectors (for example water resources and agriculture development which have the maximum implication for wetlands) have considerably higher national budgets and spending.
- **Weak inter-sectoral policy interface:** Though wetlands are affected by action related to different sectors, their integration in inter-sectoral policies remains a distinct challenge. The National Water

Policy 2002 accorded allocation priorities and identified ecology as fourth after meeting the demands for drinking water, irrigation and hydropower. There was no mention of 'wetlands'. The draft policy placed for public consultations in January 2012 (and subsequently revised) accords a higher significance to environmental concerns in general but considers wetlands from a narrow allocation perspective, thereby missing on the possibilities of including their ecosystem services as means of achieving various objectives of water management. The National Action Plan on Climate Change also does not have much to offer for the role of wetlands in climate change adaptation. Wetlands are included as one of the minor sub-components of the National Water Mission, with no reference to the role they play in climate mitigation or adaptation. The actions identified are merely limited to impact assessment of developmental projects, surveys and assessments, awareness generation and enforcement of regulatory regimes, without any semblance of being considered at risk due to maladaptation or used as an infrastructure for adaptation. Similarly, despite playing a role in sustaining livelihoods especially within rural landscapes, there is limited effort made to link wetland conservation with rural development programmes and pan-India rural employment generation initiatives as MNREGA.

- **Wetlands not identified as a distinct land use category:** The fact that wetlands are not identified as a distinct land use category makes their conservation and protection all the more difficult. The recent cases of acquiring wetlands for development of industries at Somepeta, Andhra Pradesh and Bhavnagar, Gujarat are one of the several examples wherein this lacuna is used as an opportunity for converting wetlands to alternate uses.
- **Limited knowledgebase on wetland ecosystem services and biodiversity:** The overall information base on wetlands is very limited, which is a major factor that prevents integration in sectoral policies and decision making processes. The focus of research till date has been on mapping, limnological investigations and biodiversity assessments. There is limited investment in ecosystem services research or the functional aspects of wetlands in the context of human well-being. The inventory and assessment procedures used for management planning of wetlands are not broadbased enough to ensure collection and collation of field level data on these aspects.
- **Limited capacities for integrated management:** Integrated Wetland Management is a specialized discipline which builds on multi-disciplinary knowledge system, particularly landscape scale planning. There is a dearth of specialized courses on wetland management within Indian academic institution. Limited capacities reflect in insufficient management and thereby wetland degradation.

2.5 Need for an ecosystem services approach to conservation and management of inland wetlands

Inland wetlands are one of the fastest deteriorating ecosystems globally. Evidences on Indian wetlands indicate a similar trend. Evidences also indicate that conservation and management of these ecosystems is required not only for the sake of their biodiversity or aesthetic value in landscapes, but also because societal well-being and the goals of food and water security and climate change adaptation are crucially linked to the ways wetlands are managed. The drivers of wetland degradation also largely led by sectoral economic development which fails to mainstream the values of these ecosystems into planning and decision making processes.

The focus of our national programmes for conservation of wetlands has largely been on biodiversity aspects or on regulatory approaches. There is lack of effort on connecting wetlands, their ecosystem services and biodiversity to developmental planning pathways. Sectors as water resource development and agriculture which have significant implications for the ways wetlands are managed do not take into consideration wetlands and their diversity.

An ecosystem services approach for wetlands is an effort to bring the societal dimension into their management. In fact, as is discussed in the following chapter, the coinage of the term ecosystem services itself was an effort to connect the problems of ecosystem degradation to policy making processes. It provides an opportunity to link wetlands to the societal goals of poverty alleviation, and water and food security. It allows management strategies to focus on wetlands as natural capital for the economy, and thereby promoting policy making principles which clearly take into account the impact of economic development. This approach does not necessarily run counter to the existing 'biodiversity focused' or regulatory approaches, but tends to broaden the management horizon and policy instruments. Most importantly, it provides opportunities for creating partnerships, including those with private sector to further the cause of conserving wetlands.

The implications for an ecosystem approach for design and implementation of wetlands conservation programmes are significant and multi-scalar. Investment is required into research on functional aspects of wetland science – understanding combinations of ecosystem structures and processes under which service delivery can take place. Ecosystem services need to be built into inventory and assessment protocols to enable identification and prioritization of services. Criterions would be required to help designate sites based on ecosystem services. Management plans would need to integrate services related objectives and implementation strategies. Further spatial and temporal aspects of ecosystem services led management would need to be further elucidated and integrated into management planning. The interaction of ecosystem services with livelihood capitals would need to be addressed with special focus allowing assessment of equity and social fairness related outcomes of wetland management.

Ecosystem services as a conservation argument have their own limitation and challenges as well. Firstly, its anthropocentric focus does not do full justice to intrinsic values of ecosystems, as well as systems properties as resilience. Secondly, policies often tend to focus on a narrow range of ecosystem services, thus creating trade-offs. These would need to be managed with stakeholder engagement. Plural values of ecosystem services would also need to recognized. Finally, the use of market based instruments would need to be managed carefully considering social equity contexts. As stated before, ecosystem services led management approach is not intended to replace other approaches, but is aimed at strengthening biodiversity led and regulatory approaches.

3. Valuation of ecosystem services of inland wetlands: state of art

3.1 Ecosystem services – advancing conservation through anthropocentric argumentation

The term ecosystem services reflects people-environment interactions. The coinage is believed to have been introduced by Ehrlich and Ehrlich (1981) building on the earlier literature on nature's functioning to describe a framework for structuring and synthesizing biophysical understanding of ecosystem processes in terms of human well-being (Brauman *et al.* 2007). It was in response to the compelling need felt by the natural scientists during the 1970s and the 80s to advance conservation arguments using utilitarian framing in a practical attempt to reach economic decision making circles (Westman, 1977, Armsworth *et al.* 2007). In the following decades, ecologists and economists have further elaborated the notion of ecosystems as life-support systems, providers of ecosystem services and economics benefits (Ehrlich and Mooney, 1983, De Groot, 1987, Folke *et al.* 1991). The concept got further widespread attention through the publications by Costanza *et al.* (1997) and Daily (1997). Subsequently, Millennium Ecosystem Assessment (MEA) played an important role in placing ecosystem services on the global policy agenda.

The foundational construct of the ecosystem services is appreciation of the nature-human wellbeing interlinkages as an intertwined stock-flow relationship wherein the ecosystem (including its components and processes) is perceived as a "stock of natural capital" and the benefits derived, i.e. "ecosystem services" as the flows which emanate from the stock of ecosystem asset (Barbier, 2009; Mäler *et al.* 2009). MEA defines 'natural capital' as an economic metaphor for the limited stock of physical and biological resources found on the earth (MA, 2005b). The continuing decline and degradation of natural capital stock has raised concerns on the capacity of economic systems to ensure maintenance of the natural capital stock for sustained provision of ecosystem services recognizing limits to substitution by human or manufactured capital (Barbier, 1994; Daily, 1996).

Recent work on ecosystem services have focused on the distinction between benefit, services and well-being (Boyd and Banzhaf, 2007; Fisher *et al.* 2009). TEEB assessment has emphasized distinction between 'functions' and ecological 'structures and processes' in the sense that functions represent the potential that ecosystems have to deliver a service which in turn depends on ecological structure and processes. Finally, a clear delineation is effected between ecological phenomenon (functions), their direct and indirect contribution to human welfare (services) and the welfare gains they generate (benefits). Ecosystem services are defined in TEEB as 'the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010). This basically follows the MEA definition except that it makes a finer distinction between benefits and services and explicitly acknowledges that services can benefit people in number of ways.

Millennium Ecosystem Assessment proposed the following four fold classification (MA, 2005a):

- Provisioning services comprising products obtained from the ecosystems, including food and fiber, fuel, genetic resources, biochemicals, natural medicines, pharmaceuticals, ornamental resources and freshwater
- Regulating services indicating benefits obtained from the regulation of ecosystem processes, including air quality maintenance, climate regulation, water regulation, erosion control, water purification and waste treatment, regulation of human diseases, biological control, pollination and storm protection
- Cultural services representing the non material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences, including cultural diversity, spiritual and religious values, knowledge systems, education values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values, recreation and eco-tourism
- Supporting services being necessary for production of all other ecosystem services and including soil formation, nutrient cycling and primary production

However, this typology has been found inadequate for application to various policy circumstances, especially those related to welfare assessments. Boyd and Banzhaf (2007) contend that the above scheme fails to distinguish between intermediate and final services and thereby can lead to double counting. The logic of intermediate and final ecosystem services is also adopted in the UK National Ecosystem Assessment (Bateman *et al.* 2010), the latter being used to define the last item in the chain of ecosystem functioning which inputs to the production of goods. Goods are any object or construct which generate human well-being, and benefit is the change in well-being induced by the "good" (ibid.). Several other researchers notably Fisher and Turner (2008) and Balmford *et al.* (2008) stress the need to correctly reflect the distinction between services, benefits and values to be relevant to policy application. Addressing these concerns, TEEB (2010) propose a typology of 22 ecosystem services divided into four main categories: provisioning, regulating, habitat, and cultural and amenity services. An important difference suggested in the exclusion of supporting services as nutrient cycling and food chain dynamics , which are seen as subset of ecological processes. Instead a habitat service has been identified which highlights the importance of ecosystems to provide habitat functions for species and gene – pool protectors (ibid).

It would also be worthwhile examining the critique of ecosystem services concept for a balanced appreciation of the concept. Norgaard (2009) claims that ecosystem services concept has served to blind the complexity of human predicament due to degradation of the environment. The first key critique is that the stock–flow framework used as a basis for describing ecosystem services does not fit the majority of ecological thinking, which is aligned in terms of population dynamics, food webs, biogeochemical cycles, spatial organization and co-evolutionary processes amongst others. The second line of critique is more on the application side of ecosystem services, wherein the implementation is more focused on project scales wherein a partial equilibrium approach is used to frame the decision making environment. The ceteris paribus approach to problem solving does not do justice to the current environmental issues which need revision and rethinking of institutional arrangements at regional and global levels (rather than taking them as given).

3.2 Valuing ecosystem services: frameworks and global experiences

There exist different views on meaning and sources of value. Environmental philosophy and ethics distinguishes between (a) instrumental and intrinsic values; (b) anthropocentric and biocentric or ecocentric values and (c) utilitarian and deontological values. Instrumental value of ecosystem services is the value derived from its role derived as a means towards an end other than itself. It is based on its usefulness towards achieving a goal. The contribution of fish population towards food needs of a society represents its instrumental value. However, the value of the fish population, even if it is no longer considered a food source by the society (for example due to presence of alternate sources of food) is its intrinsic value and is not related to any instrumental use. It is therefore often referred to as "non-instrumental" value.

Millennium Ecosystem Assessment (2005) defines value as "the contribution of an action or object to user specified goals, objectives or conditions" (after Farber *et al.* 2002). Valuation is defined as "the process of expressing a value for a particular good or service…in terms of something that can be counted, often money, but also through methods and measures from other disciplines (sociology, ecology and so on)" (ibid.). The perspective on valuation also differs across disciplines. In sociology, value refers to a measure for moral assessment (Barry and Oelschlaeger, 1996). In ecology, value refers to a measure of role of attributes and functions of a system to maintain ecosystem assessment and health (Bingham *et al.* 1995). Economic refers to an exchange value to maintain a system or its attributes (ibid.)

Valuation is also expressed as the relative weights we give to the various aspects of individual and social decision problem, and the weights given are the reflections of the goals and worldwide views of the community, society and cultures of which individuals are a part (eg Costanza, 1991, North, 1992).

Anthropocentric value assign intrinsic value only to humans and the rest stem due to contribution towards a human goal. The value of ecosystem services therefore is ascribed to their usefulness to human beings. The biocentric value however contends that intrinsic values can be held by all organisms, and not just limited to humans. Thus a component of intrinsic value is ascribed to nonhumans as well. Both instrumental as well as intrinsic value could be anthropocentric in nature. On the other hand, utilitarian values stem from the ability of ecosystem services to contribute to human welfare or reflect into well-being. In this sense, utilitarian values can also be considered instrumental, as the human welfare or well-being is considered to be a goal. In contrast, under the deontological approach, intrinsic value implies a set of rights which include the right to existence and which cannot be exchanged, offset, compensated or replaced.

Considered within the gamut of definitions and approaches, economic valuation of ecosystem services can be classified as an anthropocentric approach based on utilitarian principles. It includes consideration of intrinsic and instrumental values but does not reflect bio-centric or deontological values. The values assigned by an individual reflect her preferences, and in a neoclassical framework, the societal values are an aggregation of individual values. These values are inherently time and context specific, as the individual preferences are subject to several influences at a given point in time (for example information) which can change.

Within the neo-classical construct, value is a marginalistic concept that refers to impact of small changes to the state of the world. The value of ecosystem services is individual based and subjective, and context and state dependant (Goulder and Kennedy, 1997). Estimates of economic value thus reflect only the choice pattern of all- human made financial and natural resources given a multitude of socio-economical conditions as preferences, distribution of income and wealth, the state of natural environment, production technologies and expectations of the future (Barbier *et al.* 2009). Economics relies on valuation to provide society with information on relative scarcity of resources. The society can assign values to ecosystem services to the extent that these fulfil and directly or indirectly contribute to satisfaction.

The need for economic valuation arises from several reasons, key being inclusion in the decision making processes which often involves making choices between alternatives. A key logic behind economic valuation therefore is to unravel the complexities of socio-ecological relationships, make explicit how decision making would affect ecosystem service values, and to express these value changes in units that allow for their incorporation in public decision making process (Mooney *et al.* 2005). TEEB (2010) suggest atleast six reasons wherein economic valuation becomes relevant:

a) Missing markets

b) Imperfect markets and market failures

c) to understand alternatives and alternate uses for some biodiversity services

d) to address uncertainty in demand and supply of some natural resources

e) for use in conservation and natural resource management programme to support investment decision making

f) for green or natural resource accounting

Two distinct valuation paradigms are discernible from the literature. The biophysical valuation is based on a cost of production perspective that derives values from measurement of physical costs (for example labour, energy or material inputs) of producing a given ecosystem service. Preference based methods are based on models of human behaviour assuming that values arise from subjective preferences. As applied to ecosystems, the value can be seen as attributed to two aspects. The first is the value for ecosystem services derived in a given state (also referred to as output value). The second is the capacity of the system to maintain these values (termed as insurance values, Gren *et al.* 1994). The insurance value is related to system's resilience and reorganizing capacity (Holling, 1973, Walker *et al.* 2004). Ensuring resilience involves maintaining minimum amounts of ecosystem infrastructure and processing capability to remain at a given state or prevent regime shifts (ibid). The total within the TEV framework is total across value types and not across the entire ecosystem or biodiversity.

Since the seminal work by Krutilla and Fisher (1975), the total output value of the ecosystems has been generally disaggregated into two broad components, use values and non use values. Use values are associated with private or quasi – private goods for which market prices usually exist. Values, which arise from the in-situ use of a resource, are termed as the use values. The use values can be further classified into direct use values and indirect use values. The direct use values arise from commercial as well as non-commercial uses of the wetland goods and services. These can be the minor produces as reeds used for shelter, fuel wood etc. Indirect use values are the indirect support and protection provided to the economic activity and property by the wetlands through their natural functioning. Thus values created through flood protection, groundwater recharge, for example, can be classified as the indirect use values derived from the wetland ecosystem.

The non-use values are unrelated to the current use of the resource. The non-use values can further be classified into option value, bequest value and existence value. Pure existence values reflect what would be lost if a resource ceased to exist, or the value generated by existence of a resource. Bequest values are related to the altruist tendencies, the value generated by the motivation of bequeathing the resource to future generation. This basically represents the value that would be lost if a resource were degraded in quality or quantity but continued to exist. While the basis of generation of the bequest value is direct consumption of the goods or/and services generated from a resource, it does not accrue as consumption benefits to the person to whom this value is imputed. A broad typology of values is presented at Table 3.3.

Table 3.3. Value typology (Source: TEEB, 2010)

Value type	Value sub type	Explanation
Use Values		
	Direct use value	Results from direct human use of biodiversity (consumptive or non-consumptive)
	Indirect use value	Derived from regulation services provided by species and ecosystems
	Option value	Relates to the importance that people give to the future availability of ecosystem services for personal benefit

Non-use Value		
	Bequest value	Value attached by individuals to the fact that future generations will also have access to the benefits from species and ecosystems (intergenerational equity concerns)
	Altruist value	Value attached by the individuals to the fact that other people of the present generation have access to benefits provided by species and ecosystems (intra-generational equity concerns)
	Existence value	Values related to the satisfaction that individuals derive from the mere knowledge that species and ecosystems continue to exist

Within the TEV framework, values are derived from information on individual behaviour either based on existing markets or hypothetic markets. The valuation methodologies can be broadly classified into four major categories (Fig 3.4):

a) Revealed Preference Approach: These are based on ways in which ecosystem services are reflected directly in people's expenditure or in prices of other goods and services. Key tools include:

   – Market prices: In well – functioning markets preferences and marginal costs of production are reflected in a market price, which can be taken as information on value of those goods and services.

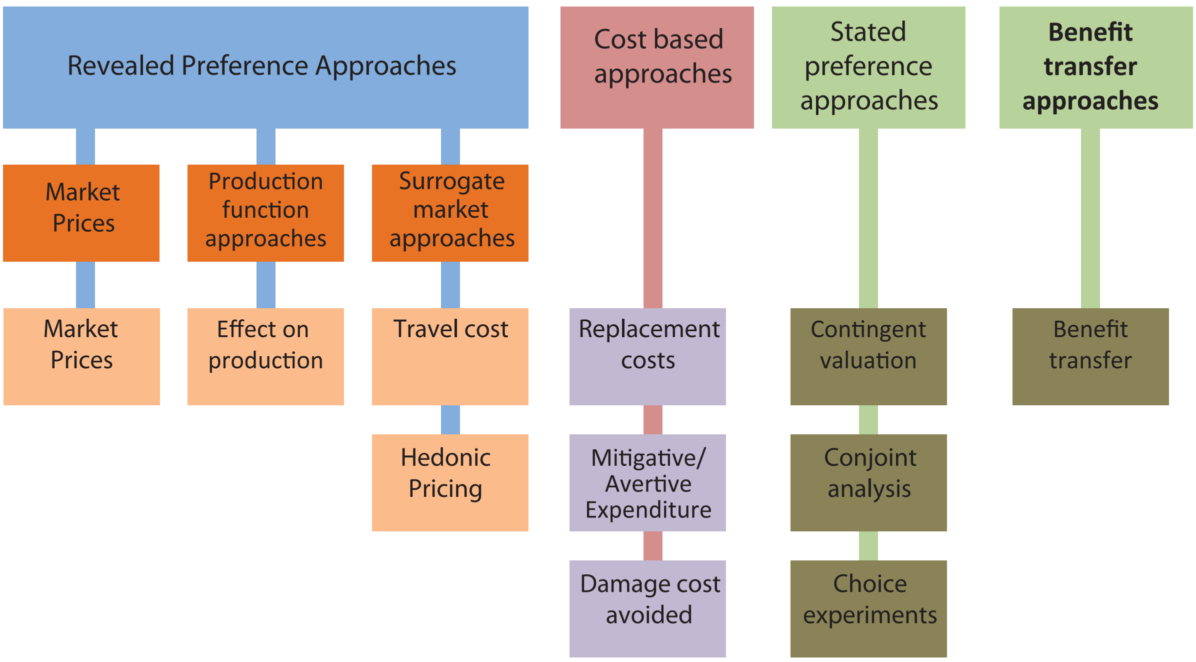
   – Production function methods: These methods stimate how much a given ecosystem service contributes to enhancement of income or productivity (Maler *et al.* 1994)

   – Surrogate market methods: These are based on the preferences revealed in existing markets that are related to ecosystem service that is subject of valuation. For example, Travel Cost method related travel expenses and other related variables to recreation features attached to a site. Hedonic pricing utilizes information about the implicit demand for an environmental attribute of marketed commodities (eg. housing prices).

b) Cost-based approaches: These approaches, including replacement costs, mitigative or avertive expenditures and damage costs avoided, look at the market trade-offs or costs avoided of maintaining ecosystems for their goods and services.

c) Stated preference approaches: Rather than looking at the way in which people reveal their preferences for ecosystem goods and services

Figure 3.4. Classification of economic valuation approaches



through market production and consumption, these approaches ask consumers to state their preference directly. The most well-known technique is contingent valuation, while less commonly-used stated preference valuation methods include conjoint analysis and choice experiments.

d) Benefit transfer: This approach uses results from other similar area / ecosystem to estimate the value of a given ecosystem / service in the study area.

A study on tidal marsh by Gosselink *et al.* (1974) was one of the earliest attempts of putting a monetary value on the services provided by the wetland ecosystems. Since then, a number of studies have been carried out on economic valuation of wetlands. Table 3.4 provides references for select studies and values generated for various ecosystem services.

Table 3.4. Economic Values for select ecosystem services

Wetland ecosystem service	Site / Location	Wetland Type	Year	Value Imputed	Study Reference
Provisioning Services					
Fisheries	Louisiana, USA	Coastal	1989	US$2,100 / ha	Costanza *et al.* 1989
	Bintuni Bay, Indonesia	Mangroves	1994	US$583.5 million/ year	Ruitenbeek, 1992
Groundwater recharge	Hadejia –Nguru Wetlands, Nigeria	Floodplains	2000	US$13,000 / day	Acharya and Barbier, 2000
Regulating Services					
Water purification	USA		1995	US$15,400/ ha	Breaux *et al.* 1995
Nutrient cycling	That Luang Marsh, Laos	Freshwater Marshes	2003	US$71,000/ year	Gerrard, 2004
	Waza Logone, Cameroon	Floodplains		US$30,00/s/q km	IUCN, 2001
		Mangroves		US$5,820/ha/ year	Lal, 1990
Storm protection	Mangroves of Koh Province, Cambodia	Mangroves		US$32 /ha	Bann, 1997
Flood protection	That Luang Marsh, Laos	Freshwater Marshes	2003	US$2.8 million/ year	Gerrard, 2004
Cultural Services					
Recreation	USA		1986-87	US$360 / user	Bergstorm *et al.*1990
Ecotourism	Kenya		1993	$450 million / year	Moran, 1994
Supporting Services					
Primary Production	Louisiana, USA	Brackishwater marshes	1979	$ 42 ,000 – 69,800 / ha	Costanza *et al.* 1989

The purpose of conducting economic valuation has been varied. There are several case studies wherein valuation has been used in a decision making context. Ruitenbeek (1992) in a study on the Bintuni Bay, Indonesia developed a cost benefit framework for evaluation of management options. Using data from household surveys, the author imputed values to forestry products, local uses of mangroves (fisheries and local products) and the biodiversity value under different management regimes. Cesar (1996) in an economic analysis of the Indonesian coral reefs used economic valuation as a tool to estimate the harmful impacts of the resource use practices of the coral reefs. An estimation of the private benefits and the social costs of practices as destructive fishery, anthropogenic pressures as urbanization, industrialization, agriculture etc., mining, sedimentation and logging on three important resource uses, i.e. fishery production, tourism and coastal protection was done. A stakeholder analysis was also done to identify the pattern of resource sharing as well as to prepare a management plan for the reefs. Similarly, Kosz (1996) used economic valuation as a tool to assess the viability of developmental projects in the case of Donau Auen national park, which consisted of riverside wetlands. Recreational and non-user benefits were estimated through a willingness to pay survey, in the different management alternatives. Of the proposed developmental projects, the in-situ conservation yielded the maximum benefits. Janssen and Padilla (1996) used a similar approach in the valuation and evaluation of management alternatives of the Pagbilao Mangrove forests. Valuation of forest products and capture fisheries was done under eight management alternatives, which were further examined in terms of equity, efficiency and environmental quality.

Several of the wetland valuation studies indicate that when both the marketed and non-marketed economic benefits are included, the total economic value of an unconverted wetland is often greater than a converted wetland. Burke *et al.* (2002) in an assessment on coral reefs in Indonesia demonstrated that a healthy coral reef could provide an average sustainable fisheries yield of 20 tonnes per year as compared to 5 tonnes per year for a reef damaged by destructive fishing practices. Similarly, sustainable fishing within the reefs could generate as much as US$ 63,000 per km^2 more over a 20 year period than over-fishing on healthy reefs. Economic assessments carried in Ream National Park, Cambodia indicated that mangroves provided subsistence support to nearly all of the resident population of Sihanoukville province (Emerton, 2003). The net value of park resources was estimated to be US$ 1.2 million a year, averaging to US$ 220 for every household living in and besides the national park. These values far exceed the benefit yielded by alternative uses: clear cutting the mangroves could generate just half of these benefits. Even prawn farming under the best conditions could realize only a fragment of the economic benefits provided by the intact system.

An understanding of the pattern of sharing and accrual of economic benefits across various stakeholder groups provides an important insight into wetlands and poverty linkages. In several circumstances, wetlands are inhabited by extremely poor and marginalized sections of society whose subsistence is linked with wetland resources. Household surveys in areas adjoining to Ream National Park, Cambodia indicated that the wetlands contributed to more than 65% of the household incomes of the families living in and around. Moran (1994) estimated the current non –consumptive value of protected areas in Kenya by foreign visitors at $ 450 million per annum providing a critical support and income generation opportunity to the local economy. A study on Hadejia-Nguru wetlands examined the value of wild resources used for food, raw material and firewood and concluded that returns from harvesting doum palm fronds and selling dried bundles provided returns three times than the average agricultural wage (Eaton and Sarch, 1996). Fisheries in Chilika in India form the primary livelihood base of over 200,000 fishers living around the lagoon (Kumar, 2004). Some of the wetland services such as flood protection and storm buffering could be of particular value to the poor who have no access or means to protect themselves against the impacts of storms or floods (FAO, 2001). Under such circumstances, decline in the resource base due to loss of wetland ecosystem services could critically affect the livelihoods of these communities exacerbating poverty, health conditions and result in migration.

The loss of wetland functions could also impose huge economic costs. Loss of wetlands was identified as one of the major reasons behind the catastrophic floods in China in 1998 which left 20 million people displaced and economic losses exceeding US $ 32 billions (EFTEC, 2005). Iftihkar (2002) examined the cost of economic costs due to inadequate water allocation decisions highlighted the crippling environmental economic costs incurred on downstream poor populations, through declining agricultural yields and fisheries production in the Indus Delta. The study concluded that rapidly escalating mangrove loss had seriously jeopardized the livelihoods of more than 135,000 people who rely on mangrove products with an economic value of US$ 1.8 million, as well as damaging coastal and marine fisheries sector generating domestic and export earning of almost US$ 125 million. Riopelle (1995) cites information on a hotel in West Lombok, Indonesia, which has spent US$880,000 over a seven-year period to restore a 250 m stretch of beach allegedly damaged by past coral mining.

More recently, there have been several attempts to define global values attached to wetland ecosystem services based on meta-analysis and benefit transfer methodologies. Costanza *et al.* (1997) in widely quoted study on valuation of the global ecosystem services put the value of the ecosystem services of terrestrial biomes at $12 319 billion annually. Woodward and Wui (2001) using results from 39 studies have come up with estimates of various ecosystem services ranging from US$ 7–2993 per hectare per year at 1990 prices. Brander *et al.* (2006) based on an analysis of 190 valuation studies drawn from various regions for five wetland types suggest the value of ecosystem services to be US$ 2,800 per hectare. De Groot *et al.* (2006) propose an estimate of US$ 3,300 per hectare per year. The authors suggest this value to be a lower bound as several services could not be linked with their corresponding economic estimates.

The most recent and comprehensive attempt to estimate monetary value of wetland ecosystem services has been made under the TEEB study wherein over 310 assessments were used to present monetary values in terms of 2007 International Dollar values (TEEB, 2010). The economic value of services provided by inland wetlands, based on 86 data points ranged between 981 and 44,957 $/ha/year. Similarly, the monetary values provided by coastal wetlands, based on 112 data points, ranged between 1,995 and 215,349 $/ha/year. Fig 3.5 and 3.6 provide estimates of monetary values and ecosystem services assessed respectively.

Figure 3.5. Economic values of inland wetlands (TEEB, 2010)

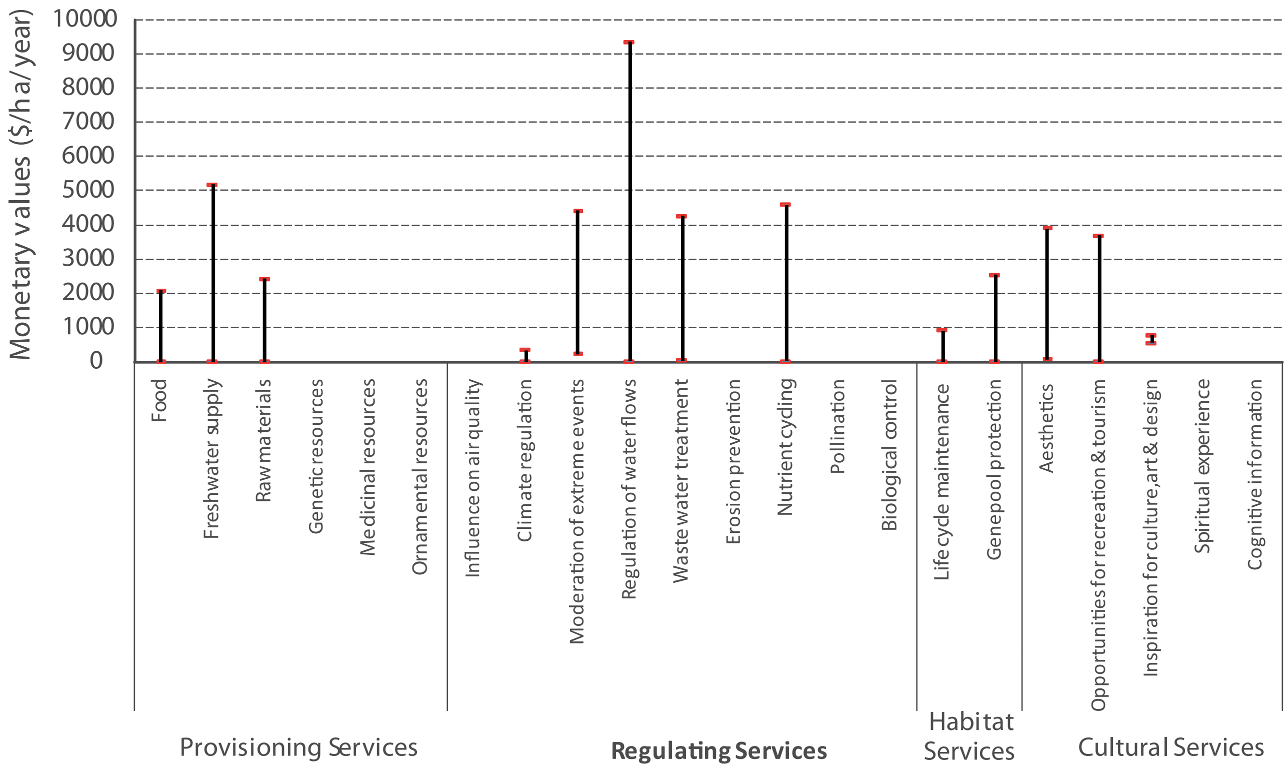
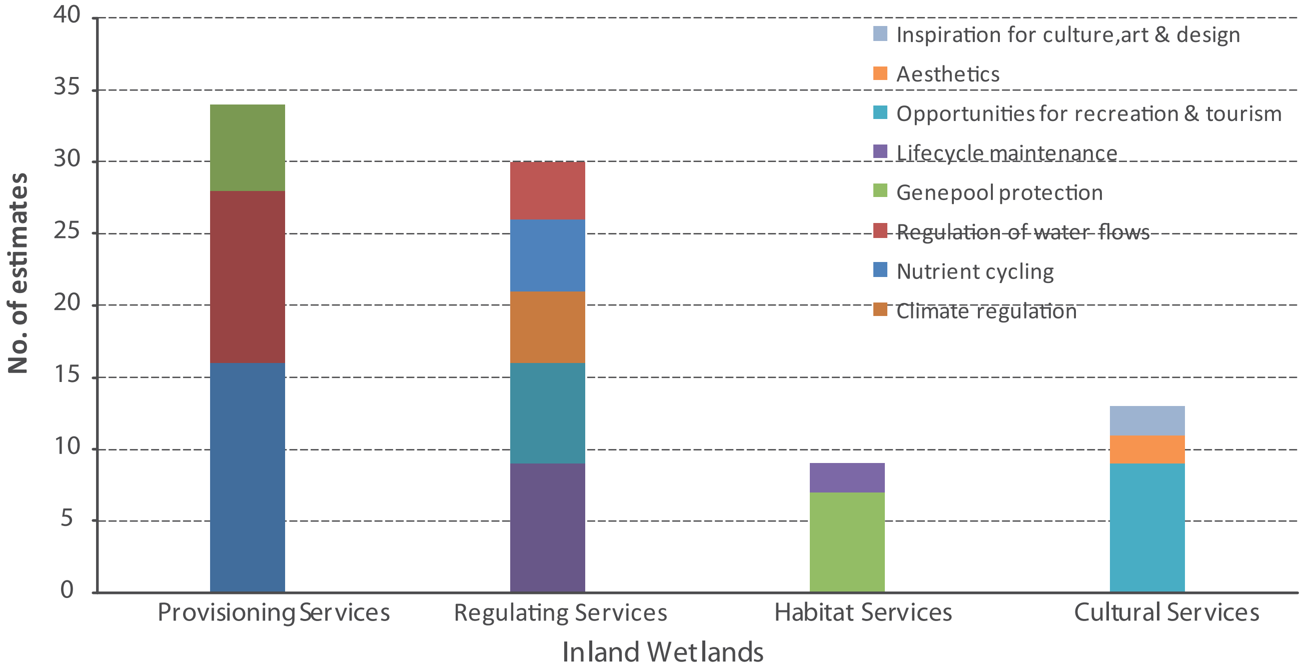


Figure 3.6. Inland wetlands ecosystem services assessed in TEEB 2010 study



3.3 Economic Valuation of inland wetlands in India

Economic valuation has received attention as a major research area only since the last decade and a half. One of the early attempts was under the Ministry of Environment and Forests's Eco-development programme, wherein an application of valuation techniques was done on Keoladeo National Park (Rajasthan) with an aim to provide possible policy options for improving people-park relationships. Subsequently, the World Bank supported 'Environmental Management Capacity Building Technical Assistance' (EMCaB) Project, implemented during 1996 – 2004 by Ministry of Environment and Forests with Indira Gandhi Institute of Development Research (IGIDR, Mumbai), Institute of Economic Growth (IEG, New Delhi), Madras School of Economics (MSE, Chennai) and other agencies put significant focus on promoting research using economic valuation tools, of which wetlands were one of the priority areas. Since then, the subject matter has been accorded high priority within research programmes of MoEF and several universities.

In the current section, an analysis of research on economic valuation of Indian inland wetlands is presented. Overall 20 studies related to economic valuation of inland waters were compiled (Table 3.5). These were analysed in terms of geographic focus, valuation context and methodologies used. Further, a range of economic values for select ecosystem services types have been generated. The analysis, however, does not make any observation on the quality of studies.

Table 3.5. Studies on economic valuation of Inland wetlands in India

S. No	Name of study	Year	Site	Values	Methodology used	Form of publi cation
1	Mukherjee and Kumar, 2012	2012	Kalobaur Beel, West Bengal	Provisioning (Fisheries, Fodder, Vegetation, Agriculture, Water)	MV, RC	JP
2	WISA, 2012	2012	Loktak Lake, Manipur	Provisioning (Fisheries, Vegetation, Water) Regulating (Water purification) Cultural (Existence)	MV, PF, RC, CVM	TR

S. No	Name of study	Year	Site	Values	Methodology used	Form of publi cation
3	Kumar, 2012	2012	Indian wetlands - selected states (Madhya Pradesh, Orissa, Gujarat, Karnataka, Chandigarh, Delhi NCR, Uttarakhand, West Bengal, Rajasthan, Maharashtra)	Physical loss in inland wetlands and per capita loss for the states	BTM	JP
4	Ramachandra *et al.* 2011	2011	Varthur Lake, Karnataka	Provisioning (Fisheries, Fodder, Vegetation, Agriculture, Water)	MV	JP
5	Bhatt and Abdullah, 2011	2011	Hokera Lake, Jammu and Kashmir	Cultural (Existence)	CVM	CP
6	Islam, 2009	2009	Tilyar Lake, Haryana	Cultural (Recreational)	TCM	PT
7	WISA, 2009	2009	Chilika Lake, Orissa	Provisioning (Fisheries, Vegetation, Water) Cultural (Recreational, Existence)	MV, TCM, CVM	TR
8	Ambastha *et al.* 2007	2007	Kabartaal Lake, Bihar	Cultural (Existence)	CVM	JP
9	Prashar *et al.* 2006	2006	Pong Dam, Himachal Pradesh	Provisioning(Fisheries, Fodder, Agriculture) Cultural (Recreational)	MV, CVM	JP
10	Pandit and Gupta, 2005	2005	Wetlands of Burdwan district, West Bengal	Provisioning (Fisheries)	MV, EM	CP
11	Pandey *et al.* 2004	2004	Indian Wetlands-selected states (Karnataka, Gujarat, Andhra Pradesh, Nagaland, Meghalaya, Sikkim)	Ecological wealth	BTA	JP
12	Ramachandra and Rajni Kanth, 2003	2003	Wetlands of Bangalore(Lake Hebbal, Amrutahalli and Rachenahalli), Karnataka	Provisioning (Fisheries, Fodder, Vegetation, Agriculture, Water)	MV	TR
13	Singh and Gopal, 2002	2002	Nainital Lake, Uttarakhand	Cultural (Recreational)	TCM	TR
14	Kumar, 2001	2001	Yamuna Floodplains, Delhi	Provisioning (Fisheries, Fodder, Vegetation) Regulating (Water purification, Groundwater recharge) Cultural (Recreational)	MV, CVM, PF, RC	CP
15	Verma *et al.* 2001	2001	Bhoj Wetlands, Madhya Pradesh	Provisioning (Fisheries, Vegetation, Water) Cultural (Recreational)	MV, CVM, EM	TR
16	WISA, 2001	2001	Harike Lake, Punjab	Provisioning (Fisheries, Vegetation) Cultural (Existence)	MV, CVM	TR
17	Maharana *et al.* 2000	2000	Khecheopalri Lake, Sikkim	Cultural (Recreational, Spiritual and inspirational)	TCM, CVM	JP

S. No	Name of study	Year	Site	Values	Methodology used	Form of publi cation
18	Chattopadhyay, 2000	2000	East Kolkata Wetlands, West Bengal	Provisioning (Fisheries, Vegetation, Agriculture)	MV	TR
19	Chopra, 1998	1998	Keoladeo National Park, Rajasthan	Cultural (Existence)	TCM	TR
20	Murty and Menkhus, 1994	1994	Keoladeo National Park, Rajasthan	Cultural (Recreational)	CVM	TR

Methodology used: MV: Market Value; RC: Replacement Cost; PF: Product Function; CVM: Contingent Valuation Method; BTM: Benefit Transfer Method; TCM: Travel Cost Method; EM: Ecological Modelling

Form of Publication: JP: Publication in peer reviewed journal; PT: Phd Thesis (unpublished); CP: Conference Paper; TR: Technical Report (unpublished)

Geographic Focus

On an overall, 15 studies were found to have focus on site specific valuation of ecosystem services. Of these, majority of the studies (7) have focused on wetlands of Indo-Gangetic floodplains, followed by 4 in the Himalayas, 3 in Peninsular India, 2 in arid/ semi-arid regions and 1 on the east coast (Map 3.3). The total number in itself in small considering the overall inland wetland extent in the country. In terms of wetland types, high altitude wetlands of Himalayas, man-made tanks, salt pans and waterlogged areas have been under-emphasized. The Deccan Peninsular region and the west coast have limited studies as compared to other regions.

Map 3.3. Location of Wetlands where Economic Valuation has been carried out

Valuation context

A majority of the studies have focused on assessing monetary values of wetland ecosystem services with an objective of demonstrating their contribution to the local or regional economy. Studies on Hokera (Jammu and Kashmir), Keoladeo National Park (Rajasthan), Nainital (Uttarakhand), Tilyar (Haryana) and Khicheopalri (Sikkim) have exclusive focus on assessing recreational values. Similarly, studies on Kalobaur Beel and East Kolkata Wetlands (West Bengal), Varthur and lakes of Bangalore (Karnataka) focus on wetland products (fish, agriculture, fodder, water, and vegetation). Very few studies (Yamuna floodplains, Delhi; Bhoj Wetlands, Madhya Pradesh; Loktak Lake, Manipur; Pong Dam, Himachal Pradesh and Chilika Lake, Orissa) have focused on multiple values of inland wetlands.

In terms of ecosystem services, one can infer an emphasis on provisioning services followed by cultural services. Regulating services have received almost no attention. Hydrological functions of wetlands, in particular (for example, flood control, water regime regulation) have not been the subject of assessments in any of the studies (Table 3.6).

Inland wetlands play a huge role in supporting local livelihoods. They way wetland ecosystem services integrate with livelihood capitals forms an important role in determining their overall well-being. Therefore, analysis of distributional aspects of wetland ecosystem services plays an important role in meaningfully interpreting wetland values from a stakeholder perspective. Again, there is a real dearth of stakeholder focus in the studies.

Singh and Gopal (2002) in their analysis of recreational values of Nainital Lake have used Participatory Rural Appraisal methods to cover perception of a range of stakeholders, such as boatmen, horsemen,

Table 3.6. Ecosystem services assessed in various valuation studies on Indian inland wetlands

	Provisioning					Regulating				Cultural				Supporting	
Site	Fisheries	Dodder	Vegetation	Agriculture	Water	Water purification	Groundwater recharge	Flood control	Climate regulation	Recreatinal	Existence	Educational	Spiritual & Inspirational	Soil formation	Nutrient cycling
Pong Dam	●	●	●	●						●					
Khecheopalri lake										●			●		
Kabartaal lake											●				
Yamuna floodplains	●	●	●			●	●			●					
East Kolkata weltlands	●		●	●											
Keoladeo National Park											●				
Varthur lake	●	●	●	●	●										
Kalobaur Beel	●	●	●	●	●										
Bhoj Weltlands	●		●		●					●					
Tilyar lake										●					
Harike lake	●		●								●				
Loktak lake	●		●		●	●					●				
Chilika lake	●		●		●					●	●				
Nainital lake										●					

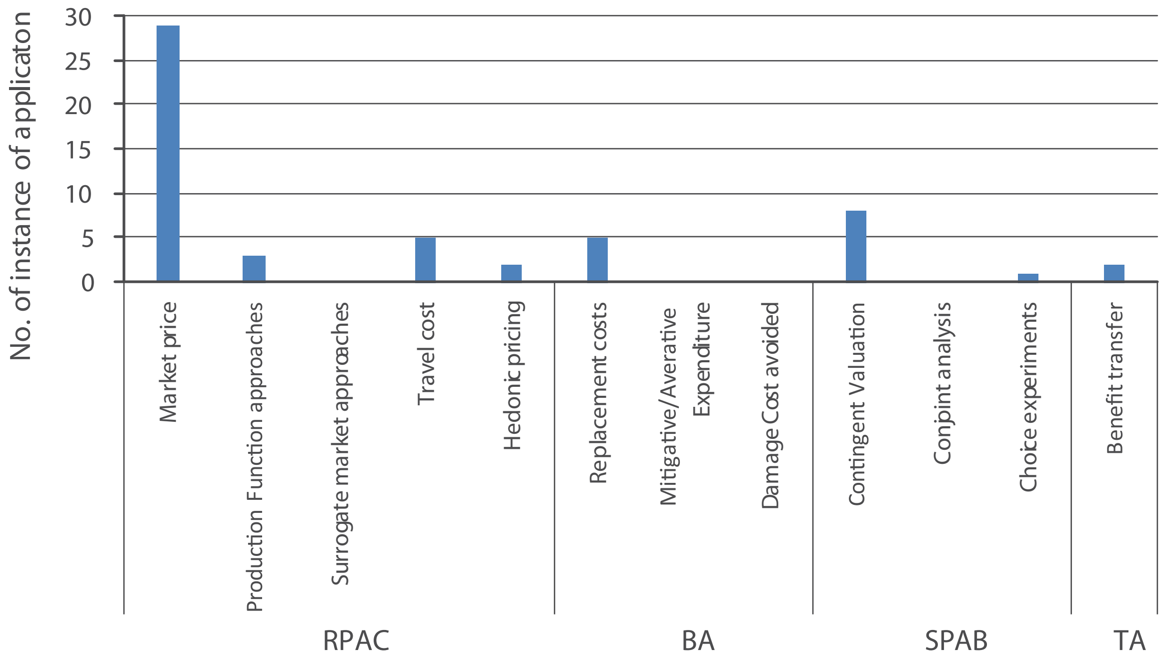
coolies and professionals and link them to the value attributes. An analysis of net and gross value added in fisheries of Chilika Lake has been linked to analysis of livelihood systems to validate distributional consequences of increase in fish landing from Chilika in the study of Kumar (2012).

Trade-offs emerging from policy decisions form a useful application area of economic valuation tools. Again, very few studies valuation studies involve assessment of trade-offs. The study of Yamuna floodplains involved assessing the opportunity cost of converting the floodplains for development and concluded that the same could not be justified on the grounds of economic efficiency (Kumar *et al.* 2001). Economic valuation was used as a tool to assess the impacts of freshwater flow regulation on ecosystem services of Chilika Lake. The assessment highlighted the positive benefits of floods to floodplain agriculture as well as downstream wetland fisheries. It also indicated that reducing the freshwater flows had negative economic consequences in terms of values of fisheries, flooding and waterlogging likely to be created due to policy decisions (WISA, 2004).
Only two studies have attempted extrapolation of economic values of wetlands or impacts of change in wetland extent to state or national level aggregates. Pandey *et al.* (2004) have computed state level aggregated values of wetland wealth using the data on wetland extent (from Directory of Wetlands, 1990) and economic values from Costanza *et al.* (1997) and Mitsh and Gosselink (2000). The study ranks Karnataka, Gujarat, and Andhra Pradesh as the states having the highest wetland wealth, and Nagaland, Meghalaya and Sikkim with lowest wealth. More recently, a framework for accounting inland wetland ecosystems for selected Indian states has been proposed by Kumar (2012). The study uses benefit transfer method to determine the impacts of physical area losses of wetlands in Gujarat, Jammu and Kashmir, Kerala, Rajasthan and West Bengal. Value estimates from 18 wetlands have been used to develop a meta-regression model to finally compute the loss of per capita wetland wealth for 1991-2001. The study concludes that the State of Jammu and Kashmir had the maximum wealth loss per capita (US$ 211.83), and an average loss of US$ 11.57 in the identified states.

Methodologies Used

A review of the methodologies used indicates a distinct preference for revealed preference based approaches (market prices, shadow prices) (Fig 3.7). This is commensurate with the focus on provisioning services, as most of the wetland products can be linked to prices in some form. Contingent Valuation follows next in terms of application; however the theoretical rigour varies across the studies. A good emphasis can also be seen on use of Travel Cost Methods to assess the recreational benefits derived from inland wetlands.

Figure 3.7. Use of various methodologies for valuation of inland wetlands



Methodologies which require validation of ecological relationships for determining ecosystem services (eg. production function, damage cost, replacement cost) in general have been under-emphasized. Again, this finding is related to the observation of lesser emphasis placed on valuation of regulating services of inland waters.

Values generated

An attempt has been made in the current report to develop a range of values for select ecosystem services based on the valuation studies. For the purpose, the outcomes of the valuation studies have been categorized with respect to services, and converted into per hectare estimates (Table 3.7). Further, as the studies pertain to different years, they have been adjusted to year 2011 using National Gross Domestic Product at Factor Costs as inflators. These values, however, are only indicative, drawn from limited sample and should be interpreted with caution.

Table 3.7. Economic values of select ecosystem services of India inland wetlands

Benefit	No. of observations	Economic Value (Rs. Per ha) at 2011 prices		
		Average	Maximum	Minimum
Fish	10	9,616	30,188	136
Fodder	4	11,350	27,983	1,850
Vegetation	9	2,258	5,946	212
Agriculture	4	12,913	41,750	704
Water	5	18,233	68,350	10
Recreational	6	5,18,859	25,08,681	335
Water purification	2	2,469	4,764	175
Groundwater recharge	1	38,798	-	-
Existence value	6	2,18,461	11,18,785	734

4. TEEB for Inland Wetlands – Proposal for a National Approach

4.1 TEEB approach and conservation and management of inland wetlands

The TEEB-International Study proposes a three tiered approach in analysing and structuring valuation of ecosystem services (TEEB 2010) comprising:

- **Recognizing value** in ecosystems, landscapes, species and other aspects of biodiversity
- **Demonstrating value** in economic terms to assist reaching decisions that consider the full costs and benefits of proposed use of an ecosystem, rather than just those costs that enter the market in the form of private goods
- **Capturing value** through mechanism that incorporate the value of ecosystems in decision making, through incentives and price signals

The current conservation and management programmes for inland wetlands in the country have an emphasis on biodiversity values as reflected in the processes through which site identification is done and management plans implemented. While the significance of such an emphasis cannot be denied or undermined, an ecosystem services approach brings to fore an explicit focus on the functional aspects of biodiversity, particularly in the context of human well-being. Given the rapid degradation of wetlands in the country, and the increasing anthropogenic pressure as indicated by evidences presented in Section 2 of this chapter, an ecosystem services led approach is expected to change the societal response not necessarily triggered by intrinsic values but necessitated for human well-being, through considering the role of wetlands in broad developmental processes of urbanization, livelihoods, food and water security and climate change adaptation. The TEEB approach can contribute in multiple ways towards this agenda, as is briefly summarized below, and explained further in the following text.

Recognizing ecosystem services	• Improving information base on ecosystem services through integration of ecosystem services assessment with wetland inventory and assessment tools (based on site and regional scale projects) • Capacity building on ecosystem services assessment
Valuing ecosystem services	• Investing into valuation of wetland ecosystem services with specific reference to ecosystem type representativeness and policy trade-off contexts • Developing national standards and benchmarks for wetland valuation
Capturing ecosystem services	• Using ecosystem services as a criterion to identify priority wetlands under National Wetland Conservation Programme • Targeting conservation and sustained provision of ecosystem services within wetland management plans • Use of economic instruments to rationalize incentive systems linked with ecosystem services, particularly rewarding local stewardship • Linking physical accounts of changes in wetland extent, biodiversity and ecosystem services to national accounting framework as a means to prioritize investment allocation and conservation efforts

Recognizing ecosystem services:

- **Improving information base on ecosystem services** – Lack of availability of credible information on ecosystem services of inland wetlands is one of the main reasons for their limited consideration in policy and decision making processes. Much of the information available at present pertains to select provisioning or cultural services which have relatively direct linkages with markets. Crucial services as the role of wetlands in regulation of hydrological regimes, supply of water and control of extreme events are under-investigated. The first step towards assisting recognition of ecosystem services is improving information base on full range of ecosystem services. This could be done through a call for evidence which could be suitably peer-reviewed. Landscape scale changes, for example the rapid loss of wetlands in Bangalore City concomitant with the urban expansion could be scientifically investigated to bring out the role of these ecosystems in developmental processes.

  Linking ecosystem services assessment within the current wetland inventory, assessment and monitoring frameworks would also assist in generating site level information on ecosystem services. Generally, site level restoration plans are funded through a management plan which includes collection and collation of baseline information on the wetlands. Currently, this includes mostly morphological, physiological and biological information and a listing of drivers and pressures as a basis for identification of interventions. Integrating ecosystem services within these assessment protocols would enable collection of information on these aspects mandatory and lead to development of very useful and significant site level baselines.

- **Capacity building** - A dedicated capacity building programme on economics of ecosystem services would assist their better recognition in policy and decision making. The ambit of the programme needs to include basic introduction to ecosystem services concepts, diagnostic tools for assessing ecosystem services, development of indicators, assessing ecosystem services trade-offs and developing a response strategy for managing these services on long term basis. In terms of targeting , site managers of various wetlands should be prioritized.

Valuing ecosystem services

- **Site level valuation** - Given the limited number of studies that address valuation of wetland ecosystem services, it is recommended that the TEEB – India process invests into valuation of specific wetland types. The site selection should be based on representativeness of ecosystem types, services as well as policy trade-off contexts. These multidisciplinary studies should, inter alea, include:

- Identification and assessment of full range of values generated from the wetland differentiated by scales and stakeholders.
- Estimation and demonstration of the value of ecosystem services using appropriate methods (social, biophysical and economic)
- Identification of mechanism for capturing thr values, particularly solutions for addressing undervaluation.

A list of sites with respect to specific policy contexts is presented at 4.3

- **Developing valuation benchmarks** - The review of economic valuation studies indicates that very few of these have been validated through a peer-review process, and there is high variability in the research quality. To further develop capacity in the field of economic valuation, it is important that suitable benchmarks are developed for conducting economic valuation assessments – including the data collection procedures, econometric modelling and interpretation of results. In the Indian contexts, development of methodologies that link valuations with distributive efficiency and stakeholder dynamics needs to be stressed.

Capturing ecosystem services

- **Ecosystem services as site identification criterion** – The National Wetland Conservation Programme (NWCP), which is the key national level initiative for promoting conservation and wise use of wetlands uses the Ramsar Convention criterions for selection of priority sites. These mostly relate to biodiversity elements of wetlands. A key step for capturing ecosystem services is to use these as criteria for identification of wetlands of national priority. Since the NWCP also provides funding for implementation of site management plan, a key outcome of use of ecosystem services based site identification criterion would be enhanced allocation of financial and human resources for these sites.
- **Targeting ecosystem services within wetland management plans** – Wetland management plans provide the key instruments for investment in wetland restoration. A typical management plan identifies specific site or habitat quality targets that are met through implementation of action plans. Including ecosystem services related targets, for example achieving a desired level of hydrological regulation through restoration of wetlands would bring explicit focus and investment into their sustained provision and management. However, setting such targets would require creation of appropriate baseline on ecosystem functioning through biophysical modelling.
- **Rationalizing incentive systems** – A key driver of wetland degradation and loss is policy decisions which do not fully internalize the full range of ecosystem services values and thereby provide incentives for alternate use. The costs and benefits of ecosystem service provision are shared by different stakeholder groups thereby creating different decision making environment and incentive for actions. A key step towards capturing ecosystem services is through rationalizing these incentives.

Payments for Ecosystem Services (PES) and related tools have emerged as mechanism through which the benefits and costs of ecosystem services provision could be equitably shared and their management incentivized. However, experiences from application of these instruments have revealed that considerable work needs to be done beforehand for characterization of ecosystem services, developing capacities of buyers and sellers, building and empowering institutions and monitoring and evaluation. The application of PES instruments needs investment into these aspects, with careful consideration to social contexts. Some key candidates for application would be wetlands which have been regulated for hydropower development or are used as urban infrastructure, wherein the wetland management and markets (eg. for hydropower) could be connected. In the opinion of the authors, development of PES instruments should be seen a middle order priority, once sufficient evidence base of ecosystem service provision has been established, characterised with clearly demarcated stakeholders.

Recently, some innovative application on inventive systems has been attempted through linking microcredit with conservation targets. One such instrument is Biorights, a financial mechanism that addresses poverty trap by integrating sustainable development and environmental conservation (Eijk and Kumar, 2008). In return for provision of micro-credits, local community involves in ecosystem protection and restoration. Upon successful delivery of conservation services, these microcredits are converted in definitive payments. Thus the approach enables community involvement in conservation while providing sustainable alternatives to harmful development practices. Such instruments could be linked to wetland management wherein there are high anthropogenic pressures and there are opportunities for involving communities as resource stewards.

- Developing green accounts for wetlands- Linking physical accounts of changes in wetland extent, biodiversity and ecosystem services to national accounting framework as a means to prioritize investment allocation and conservation efforts would be an ultimate objective that would help clarify the contribution wetlands make to the national economy and also guide investments into restoration and wise use.

4.2 Proposed strategic areas and methodology

Based on the analysis of drivers and pressures on wetlands, the need and relevance of an ecosystem services led approach for wetland conservation, and a review of state of art of valuation of inland wetlands, it is proposed that the TEEB – Inland wetlands focuses on three strategic areas: a) ecosystem services - policy and decision making support, b) ecosystem services valuation, and c) capacity building, communication and awareness generation. A project design framework is discussed below:

Goal	Ecosystem services and biodiversity are mainstreamed into policy and decision making for conservation and wise use of inland wetlands		
Strategic Area	Ecosystem Services and Policy and Decision Making Support	Valuation of wetland ecosystem services	Capacity building, communication and awareness generation
Objective	Develop decision support systems for integration of ecosystem services and biodiversity in policy and decision making for conservation and wise use of inland wetlands	Create policy –centric evidence base on values of ecosystem services and biodiversity of inland wetlands	Build and enhance capacity for ecosystem services assessment and integration in management of inland wetlands Enhance awareness on ecosystem services and biodiversity of inland wetlands
Activities	Development of a framework for integration of ecosystem services into wetland inventory, assessment and monitoring systems Design and implementation of framework for identification and prioritization of wetlands on the basis of ecosystem services Ecosystem services based management planning for priority wetlands	Development of a methodology for identification and valuation of inland wetland ecosystem services for a defined policy context Implementation of valuation assessments for pilot sites Piloting ecosystem services linked incentive systems for restoration and sustained provision of wetland ecosystem services	Capacity building needs assessment Training workshops on ecosystem services assessment, valuation and other topics as identified through needs assessment Exchange programmes Communication and outreach

	Results based framework for wetland conservation and wise use at state and national levels (use of ecosystem services indicators) Design and implementation of ecosystem services accounting framework for inland wetlands		
Implem entation methodology	Constitution of a policy team for implementation of activities corresponding to the component. The policy team to be responsible for liaising with the concerned officials of the MoEF and state governments to ensure that the project activities and results are relevant and integrated into policy and decision making	Constitution of an expert panel for design of a common methodology framework for identification and valuation of ecosystem services Request for Proposals from shortlisted agencies for implementation of valuation studies Implementation of the valuation through multi-disciplinary teams involving ecologists, economists, hydrologists and livelihood specialists Peer review and implementation support to the studies by the expert group Collation of valuation outcomes into an evidence base	Capacity building component should respond to a needs assessment. The project should endeavour with specialized academic and policy institutions to design courses around TEEB approach. In the medium and long term these courses could be internalized into the academic curriculum of universities.

4.3 Study sites and ecosystem services focus

The review of the valuation studies conducted in India thus far have indicated that the field is largely underdeveloped with limited capacity and research investment. In terms of ecosystem services, much of the focus has been on provisioning and cultural services, with limited or no studies addressing regulating services, particularly hydrological regime regulation function of wetland systems. Wetlands in the Deccan and the coast have also received comparatively lesser attention.

The literature review also indicates that investment into economic valuation of ecosystem services are useful in three circumstances:

a) When there is a need to demonstrate the value of ecosystem services in terms of contribution to the local, regional or national economy

b) When there are policy trade-offs (linked to stakeholders, spatial, temporal or ecosystem services types) involved over use of wetlands

c) When multi-functional use of wetlands is being considered

Based on these criterions an indicative list of candidate sites is presented below alongwith the policy and decision making contexts which could be used for structuring economic valuation assessments.

Loktak Lake, Manipur	Impact of upstream water resources development and downstream regulation on wetland ecosystem services and biodiversity; mechanism for rationalization of incentive systems for water management
Keoladeo National Park, Bharatpur	Linkages of upstream water management with maintenance of park biodiversity; mechanism for rationalization of incentive systems for water management
Tsokar – TsoMorori, Ladakh	Impact of tourism on wetland ecosystem services ; mechanism for rationalization of incentive systems for sustainable tourism
Chilika Lake, Orissa	Impact of hydrological intervention on ecosystem services ; assessment of distributive efficiency of benefits of restoration ; mechanism for making market chains related to fisheries responsive to sustainable fisheries
Deepor Beel, Assam	Role in flood mitigation ;impacts of urban development on ecosystem services
Temple tanks, Tamil Nadu	Cultural and religious values along with role in water harvesting and hydrological regime regulation ; design of incentive systems for local community stewardship for management of temple tanks
Nizam Sagar, Hyderabad	Role of inland water systems as urban infrastructure; capturing ecosystem services through economic instruments
Wetlands of Gujarat	Regulation / fragmentation of hydrological regimes resulting into loss of ecosystem services; design of incentive systems for local community stewardship for management of wetlands
Vembanad Kol Backwaters, Kerala	Agriculture – inland water ecosystem services tradeoffs, impact of unmanaged tourism on ecosystem services
Pulicat Lake, Andhra Pradesh / Tamil Nadu	Role of trans boundary cooperation in sustaining ecosystem services of inland waters

References

Acharya, G. and Barbier, E. 2000. Valuing ground water recharge through agricultural production in Hadejia- Nguru wetlands in northern Nigeria. Agricultural Economics 22 (3): 247-259.

Alfred, J.R.B. 1998. Faunal Diversity in India: An Overview, ENVIS Centre, Zoological Survey of India, Calcutta, India.

Alfred, J.R.B. 2006. Faunal resources and sustainable utilization. In: Verma, D.D., Arora, S. and Rai, R.K. (eds.), Perspectives on Biodiversity: A Vision for Megadiverse Countries. Ministry of Environment and Forests, Government of India, New Delhi, India.

Alfred, J.R.B. and Nandi, N.C. 2000. Faunal Diversity in Indian Wetlands. Enviro News 4(4&5).

Ambastha, K., Hussain, S.A. and Badola, R. 2007. Resource dependence and attitudes of local people toward conservation of Kabartal wetland: A case study from the Indo-Gangetic plains. Wetlands Ecology and Management 15: 287-302.

Ambastha, K., Hussain, S.A. and Badola, R. 2007. Social and economic consideration in conserving wetlands of indo-gangetic plains: A case study of Kabartal wetland, India. Environmentalist 27:261-273.

Armsworth, P.R., Chan, K., Chan, M.A., Daily, G.C., Kremen, C., Ricketts, T.H. and Sanjayan, M.A. 2007. Ecosystem-service science and the way forward for conservation. Conservation Biology 21(6):1383–1384.

Balmford, A., Rodrigues, A., Walpole, M.J., ten Brink, P., Kettunen, M., Braat, L. and de Groot, R. 2008. Review of the Economics of Biodiversity Loss: Scoping the Science, European Commission, Brussels.

Bann, C. 1997. An economic analysis of alternative mangrove management strategies in Koh Kong Province Cambodia. EEPSEA Research Report. Environment and Economics Program for South East Asia, International Development Research Centre, Ottawa.

Barbier, E.B. 1994. Valuing Environmental Functions: Tropical Wetlands. Land Economics 70:155-173.

Barbier, E.B. 2009. Ecosystems as Natural Assets. Foundations and Trends in Microeconomics 4(8): 611-681.

Barbier, E.B., Baumgartner, S., Chopra, K., Costello, C., Duraiappah, A., Hassan, R., Kinzig, A., Lehman, M., Pascual, U., Polasky, S. and Perrings, C. 2009. The valuation of Ecosystem Services. In Naeem, S., Bunker, D.E., Hector, A., Loreau, M. and Perrings, C. (eds.). Biodiversity Ecosystem Functioning and Human Wellbeing: An Ecological and Economic Perspective, Oxford University Press, Oxford.

Barman, R.P. 1998. Faunal diversity in India- Pisces. ENVIS Centre, Zoological Survey of India, Calcutta, India. 418-426pp

Barry, D. and Oelschlaeger, M. 1996. A science for survival: values and conservation biology. Conservation Biology 10: 905-11.

Bateman, I.J., Mace, G.M., Fezzi, C., Atkinson, G., Barbier, E.B. and Turner, K. 2010. Economic analysis for ecosystem services assessment, Draft paper, National Ecosystem Assessment, Defra, London.

Bergstrom, J.C., Stoll, J.R., Titre, J.P. and Wright, V.L. 1990. Economic Value of Wetlands-based Recreation. Ecological Economics 2: 129-147.

Bhatt, M. and Abdullah, A. 2011. Valuing Biodiversity of Hokera Wetland Reserve: "A Contingent Valuation Approach" Conference Paper.

Bingham, G., Brody, M., Bromley, D., Clark, E., Cooper, W., Costanza, R., Hale, T., Hayden, G., Kellert, S., Nargaard, R., Norton, B., Payne, J., Russell, C. and Suter, G. 1995. Issue in Ecosystem Valuation: Improving Information for decision making. Ecological Economics 14 (2): 73-90.

Boyd, J. and Banzhaf, S. 2007. What are ecosystem services? The need for standardized environmental accounting units. Ecological Economics 63(2-3):616-626.

Brander, L.M., Florax, R.J.G.M. and Vermaat, J.E. 2006. The empirics of wetland valuation: A comprehensive summary and a meta-analysis of the literature. Environmental and Resource Economics 33:223-250.

Brauman, K.A., Daily, G.C., Duarte, T.K. and Mooney, H.A. 2007. The nature and value of ecosystem services: an overview highlighting hydrologic services. Annual review of the Environment and Resources 32:67-98.

Breaux, A., Farber, S. and Day, J., 1995. Using natural coastal wetlands systems for wastewater treatment - an economic benefit analysis. Journal of Environmental Management 44:285–291.

Burke, L., Selig, E. and Spalding, M. 2002. Reefs at Risk in Southeast Asia. World Resources Institute, Washington, DC.

Cesar, H. 1996. Economic analysis of Indonesian coral reefs. The World Bank, Washington, DC.

Chattopadhyay, K. 2000. Environmental Conservation and Valuation of East Calcutta Wetlands, Final Report, Indira Gandhi Institute of Development Research, Mumbai, India.

Chopra, K. 1998. The valuation of biodiversity within protected areas: Alternative approaches and case study. Institute of Economic growth, New Delhi, India.

Costanza, R., d'Arge, R., deGroot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. and van den Belt, M. 1997. The Value of World's Ecosystem Services and Natural Capital. Nature 387: 253-260.

Costanza, R., ed. 1991. Ecological Economics: The Science and Management of Sustainability. New York, Columbia University Press.

Costanza, R., Farber, S.C. and Maxwell, J. 1989. Valuation and management of wetland ecosystems. Ecological Economics 1:335–361.

Daily, G. 1997. Nature's services: Societal Dependence on Natural Ecosystems, Island Press, Washington, DC.

Daly, H. 1996. Introduction to Essays toward a Steady-State Economy. In Daily, H. and Townsend, K.N. (eds.). Valuing the earth: Economics, Ecology, Ethics, The MIIT Press, Cambridge, MA, 11-47pp.

De Groot, R.S. 1987. Environmental functions as a unifying concept for ecology and economics. The Environmentalist 7(2):105-109.

De Groot, R.S., Stuip, M.A.M., Finlayson, C.M. and Davidson, N. 2006. Valuing wetlands: guidance for valuing the benefits derived from wetland ecosystem services, Ramsar Technical Report No. 3/CBD Technical Series No. 27. Ramsar Convention Secretariat, Gland, Switzerland & Secretariat of the Convention on Biological Diversity, Montreal, Canada.

Deka, J., Tripathi, O.P. and Khan, M.L. 2011. A multi-temporal remote sensing approach for monitoring changes in spatial extent of freshwater lake of Deepor Beel- Ramsar Site, a major wetland of Assam. Journal of Wetland Ecology 5:40-47.

Eaton, D. and Sarch, M.T. 1996. The Economic importance of wild resources in the Hadejia-Nguru wetlands, Nigeria. CREED Working Paper No. 13. International Institute for Environment and Development, London.

EFTEC, 2005. The Economic, Social and Ecological Value of Ecosystem Services: A Literature Review. Final report for the Department for Environment, Food and Rural Affairs. Economics for the Environment Consultancy, London.

Ehrlich, P.R. and Ehrlich, A.H. 1981. Extinction: the cause and consequences of the disappearance of species. Random House, New York.

Ehrlich, P.R. and Mooney, H. A. 1983. Extinction, substitution, and ecosystem services. Biosciences 33: 248-254.

Eijk, P. Van and Kumar, R. 2008. Bio-rights in theory and practice. A financing mechanism for linking poverty alleviation and environmental conservation. Wetlands International, Wageningen, The Netherlands.

Emerton, L. 2003. Valuing Wetlands In Decision-Making: where are we now? Integrating Wetland Economic Values into River Basin Management: Wetland Valuation Issues Paper #1, IUCN Asia, Colombo, Sri Lanka. 7pp

FAO, 2001. Reducing Agricultural Vulnerability to Storm- Related Disasters. Committee on Agriculture, Food and Agriculture Organization, Rome.

Farber, S.C., Costanza, R. and Wilson M.A. 2002. Economics and ecological concepts for valuing ecosystem services. In: The dynamics and value of ecosystem services: Integrating economic and ecological perspectives. Ecological Economics 41:375-392.

Fisher, B. and Turner, R.K. 2008. Ecosystem services: Classification for valuation. Biological Conservation 141:1167-1169.

Fisher, B., Turner, R.K. and Morling, P. 2009. Defining and classifying ecosystem services for decision making. Ecological Economics 68:643-653.

Folke, C., Hammer, M. and Jansson, A.M. 1991. Life-support value of ecosystems: A case study of the Baltic region. Ecological Economics 3(2):123-137.

Gerrard, P. 2004. Integrating Wetland Ecosystem Values into Urban Planning: The Case of That Luang Marsh, Vientiane, Lao PDR. IUCN - The World Conservation Union Asia Regional Environmental Economics Programme and WWF Lao Country Office, Vientiane.

Ghosh, A.K., Bose, N., Singh, K.R.P. and Sinha, R.K. 2004. Study of spatio-temporal changes in the wetlands of north Bihar through remote sensing. In: Proceeding of the ISCO 2004-13th International Soil Conservation Organisation Conference-Brisbane, 2004, Conserving Soil and Water for Society, Sharing Solutions.

Gogoi, R. 2007. Conserving Deepar Beel- Ramsar Site, Assam. Current Science 93(4): 445-446.

Gopal, B. 1987. Water hyacinth. Aquatic Plant, Studies 1. Amsterdam, The Netherlands, Elsevier Science 471pp.

Gopal, B. and Sah, M. 1995. Inventory and Classification of Wetlands in India. Plant Ecology 118(1-2):39-48.

Gosselink, J.G., Odum, E.P. and Pope, R.M. 1974. The Value of Tidal Marsh. Center for Wetland Resources, Lousiana State University.

Goulder L.H., Kennedy F. 1997. Valuing ecosystem services. In: Daily, G. (ed). Ecosystem services: Their nature and value. Washington DC: Island Press. 23-48pp.

Gren, I.M., Folke, C., Turner, R.K. and Bateman, I. 1994. Primary and secondary values of wetland ecosystems. Environment and Resource Economics 4:55-74.

Holling, C.S. 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematic 4:1-23.

Iftikhar, U. 2002. Valuing the economic costs of environmental degradation due to sea intrusion in the Indus Delta. In: IUCN, Sea Intrusion in the Coastal and Riverine Tracts of the Indus Delta - A Case Study. Karachi. The World Conservation Union- Pakistan Country Office.

Islam, A.K.M. Nazrul 2009. Economic valuation of Biodiversity: A comparative study of selected wetlands of India and Bangladesh. Ph.D. Thesis submitted to Department of Economics, Jamia Milia Islamia, Central University, New Delhi, India.

ICAR 2011. Handbook of Fisheries and Aquaculture, ICAR, New Delhi, pp 1116

IUCN, 2001. Economic Value of Reinundation of the Waza Logone Floodplain, Cameroon. IUCN.

Janssen, R. and Padilla, J.E. 1996. Valuation and evaluation of management alternatives for the Pagbilao mangrove forest. CREED Working Paper No. 9. International Institute for Environment and Development, London.

Kosz, M. 1996. Valuing riverside wetlands: the case of the “Donau-Auen” National Park. Ecological Economics 16:109-127.

Krutilla, J. and Fisher, A.C. 1975. The Economics of Natural Environments : Resources for the Future, John Hopkins University Press , Washington, DC.

Kumar, A., Sati, J.P., Tak, P.C. and Alfred, J.R.B. 2005. Handbook on Indian Wetland Birds and Their Conservation. Pub: Director, Zoological Survey of India, Kolkata. 468 pp.

Kumar, A.B. 2000. Exotic fishes and freshwater fish diversity. Zoo’s Print Journal15: 363-367.

Kumar, P. 2001. Economic Valuation of Yamuna Floodplains. In: J. Parikh (ed.) Reconciling Environment and Economics, Indira Gandhi Institute of Development Research, Mumbai, India.

Kumar, P. 2012. Measuring Natural Capital: Accounting of Inland Wetland Ecosystems from Selected States of India. Economic & Political Weekly 47: 77-84.

Kumar, P., Babu, C.R., Sharma, S.R., Love, A. and Prasad, L. 2001. Valuation of Ecosystem Services: A Case Study of Yamuna Floodplain in the Corridors of Delhi. Under the World Bank Aided Environmental Management Capacity Building Programme. Mimeograph, IEG, Delhi, India.

Kumar, R. 2004. Rapid economic assessment of Chilika. Chilika Newsletter. Chilika Development Authority and Wetlands International – South Asia, New Delhi.

Kumar, R. 2012. Institutions and Valuation of Wetland Ecosystem Services. Ph.D. Thesis submitted to Department of Economics, University of Delhi, New Delhi, India.

Ladhar, S.S., Chauhan, M., Handa, S.M. and Jerath, N. 1994. Ramsar sites of India- Harike Lake, Punjab. WWF-India, New Delhi, India.

Lal, P.N. 1990. Conservation or Conversion of Mangroves in Fiji. East-West Environment and Policy Institute, Honolulu Occasional Paper No. 11, 108 pp.

Li, Z.W.D., Bloem, A., Delany, S., Martakis, G. and Quintero, J.O. 2009. Status of Waterbirds in Asia - Results of the Asian Waterbird Census: 1987-2007. Wetlands International, Kuala Lumpur, Malaysia.

MA, 2005a. Ecosystems and Human Well-being: Millennium Ecosystem Assessment Synthesis, Island Press, Washington , DC.

Maharana, I., Rai, S.C. and Sharma, E. 2000. Valuing ecotourism in a sacred lake of the Sikkim Himalaya, India. Environmental Conservation 27:269–277.

Mäler, K.G., Aniyar, S. and Jansson, A. 2009. Accounting for Ecosystems.Environmental and Resource Economics 42: 39-51.

Menon, N.G. 1979. Studies on the biology and fishery of the giant marine catfish Tachysurus thalassinus (Ruppell). Ph.D.Thesis of the University of Cochin.

Mitsch, W.J. and Gosselink. J.G. 2000. Wetlands. 3rd Ed. John Wiley & Sons, New York. 920pp.

Mooney, H., Cropper, A. and Reid, W. 2005. Confronting the Human Dilemma: How can Ecosystems provide Sustainable Services to benefit Society? Nature 434: 561-562.

Moran, D. 1994. Contingent Valuation and Biodiversity: Measuring the user Surplus of Kenyan protected areas. Biodiversity and Conservation 3: 663–684.

MoRD and ISRO, 2010. Wasteland Atlas of India. Ministry of Rural Development, New Delhi and National Remote Sensing Centre, Hyderabad, India.

Moular, S. and Walker, S. 1998. Report of the Conservation Assessment and Management Plan. Workshop on freshwater fishes of India. Zoo outreach Organization/CBSG, Coimbatore, India, 156pp.

Mukherjee, S. and Kumar, M. D. 2012. Economic valuation of a multiple use wetland water system: A case study from India. IWA Publishing London, U.K. Water Policy 14(1):80-98.

Murty, M.N. and Menkhus, S.M. 1994. Economic Aspects of Wildlife in Developing Countries: A Case Study of Keoladeo National Park, Bharatpur, India. In: Society for Promotion of Wasteland Development, Valuing India’s Natural Resources, New Delhi, India.

National Environment Policy, 2006. Ministry of Environment and Forests, Government of India, New Delhi, India.

Navatha, K., Pattanaik, C. and Reddy, S. 2011. Assessment of wetland dynamics in Sirohi district of Rajasthan, India using remote sensing and GIS techniques. Journal of Wetland Ecology Cote 5:66-72.

Norgaard, R.B. 2009. Ecosystem services: From eye-opening metaphor to complexity blinder. Ecological Economics 69(6): 1221-1227.

North, D.C. 1992. Transactions costs, institutions, and economic performance. Institute for Contemporary Studies, San Francisco, California, USA.

Pandey, J.S., Joseph, V. and Kaul, S.N. 2004. A Zone-Wise Ecological Economic Analysis of Indian Wetlands. Environmental Monitoring and Assessment 98:261-273.

Pandit, C. and Gupta, K. 2005. Valuation of Inland Wetlands: A study on some selected wetlands for the Burdwan District of West Bengal. Paper presented at the Fourth Biennial Conference of INSEE on “Ecology and Human Well Being held at Indira Gandhi Institute of Development Research, Mumbai, India.

Pattanaik C. and Reddy, C.S. 2007. Need for the conservation of wetland ecosystems: A case study of Ansupa lake (Orissa, India) using remote sensing based data. National Academy Science Letters 30(5&6): 161-164.

Prasher, R.S., Negi, Y.S. and Kumar, V. 2006. Valuation and Management of Wetland Ecosystem - A Case Study of Pong Dam in Himachal Pradesh, India. Man & Development 28(3):77-92.

Ramachandra, T.V. and Rajinikanth, R. 2003. Economic valuation of wetlands. CES technical report no. 101. Centre for Ecological Sciences, IISc., Bangalore, India.

Ramachandra, T.V. and Kumar, U. 2008. Wetlands of Greater Bangalore, India: Automatic Delineation through Pattern Classifiers. Electronic Green Journal (26).

Ramachandra, T.V., Alakananda, B., Ali, R. and Khan, M.A. 2011. Ecological and socio-economic assessment of Varthur wetland, Bengaluru, India. Journal of Environmental Science and Engineering 53(1):101-108.

Riopelle, J.M. 1995. The economic valuation of coral reefs: A case study of west Lombok, Indonesia, Thesis. Dalhousie University, Halifax, Canada.

Ruitenbeek, J. 1992. Mangrove Management: An economic analysis of management options with a focus on Bintuni Bay, Iriyan Jaya. Dalhousie University, Halifax, 90pp.

SAC, 1998. Wetlands of India, Project Report, RSAM/SAC/RESA/PR/01/98, Space Applications Centre (ISRO), Ahmedabad, India, 240pp.

SAC, 2011. National Wetland Atlas, SAC/EPSA/ABHG/NWIA/ATLAS/34/2011, Space Applications Centre (ISRO), Ahmedabad, India, 310pp.

Sarkar, A. and Jain, S. 2008. Using Remote Sensing Data to Study Wetland Dynamics – A Case Study of Harike Wetland. In: Proceedings of Taal 2007: The 12th World Lake Conference, 680-684 pp.

Scott, D.A. 1989. A Directory of Asian Wetlands. IUCN, Gland, Switzerland, and Cambridge, United Kingdom.

Singh, S.P. and Gopal, B. 2002. Integrated Management of Water Resources of Lake Nainital and its Watershed: An Environmental Economics Approach. Final Report, Indira Gandhi Institute of Development Research, Mumbai, India.

TEEB, 2010. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.

Trisal, C.L. 1996. Wetlands biodiversity in the Himalayan Region. In: Changing Perspective of Biodiversity Status in the Himalaya. British Council Division, British High Commission. 2.6: 63-711.

Trisal, C.L. and Kumar, R. 2008. Integration of High Altitude Wetlands into River Basin Management in the Hindu Kush Himalayas: Capacity Building Needs Assessment for Policy and Technical Support. Wetlands International-South Asia, New Delhi, India.

Trisal, C.L. and Manihar, Th. 2004. The Atlas of Loktak Lake. Wetlands International-South Asia and Loktak Development Authority, New Delhi, India.

Trisal, C.L., Tabassum, T. and Kumar, R. 2008. Water Quality of the River Yamuna in the Delhi Stretch: Key Determinants and Management Issues. Clean 36(3):306–314.

Varghese, S., Narayanan, S.P., Prashob Raj, V.M., Prasad, V.H. and Prasad, S.N. 2008. Analyses of Wetland Habitat Changes and its Impacts on Avifauna in select Districts of the Indo-Gangetic Plains of Uttar Pradesh, India, Between 1972 and 2004. In: Proceedings of Taal 2007: The 12th World Lake Conference, 2045-2055 pp.

Venkataraman, K. 2003. Natural Aquatic Ecosystems of India, Thematic Biodiversity and Action Plan. The National Biodiversity Action Plan: 1-275pp.

Verma, M., Bakshi, N. and Nair, R.P.K. 2001. Economic Valuation of Bhoj Wetlands for Sustainable Use. Indian Institute of Forest Management, Bhopal. Under World Bank Aided India: Environmental Management Capacity Building Technical Assistance Project.

Vijayan, V.S., Prasad, S.N., Vijayan, L. and Muralidharan, S. 2004. Inland Wetlands of India - Conservation Priorities. Salim Ali Centre for Ornithology and Natural History. Coimbatore, India.

Walker, B.H., Holling, C.S., Carpenter, S.R. and Kinzig, A.P. 2004. Resilience, adaptability and transformability. Ecology and Society 9(2):5.

Westman, W. 1977. How much are nature's services worth? Science 197:960-964.

Wetlands International, 2010. Wetlands and Water, Sanitation and Hygiene (WASH)-Understanding the linkages. Wetlands International, Ede, The Netherlands.

WISA, 2001. Economic Valuation of Harike Lake, Punjab. Project Report, Wetlands International-South Asia, New Delhi, India.

WISA, 2004. Socio-economic Assessment of Environmental Flow Scenarios of Chilika. Final Report, Wetlands International-South Asia, New Delhi. India

WISA, 2005. Management Action Plan for Rudrasagar, Tripura. Action Plan, Wetlands International-South Asia, New Delhi, India.

WISA, 2007. Comprehensive Management Action Plan for Wular Lake, Kashmir. Final Report, Department of Wildlife Protection, Govt. of Jammu & Kashmir. Wetlands International-South Asia, New Delhi, India.

WISA, 2008. Management Plan for East Kolkata Wetlands. Final Report, Wetlands International-South Asia, New Delhi, India.

WISA, 2009. Economic Evaluation and Integrated Resource Management of Chilika Lagoon. Project Report, Wetlands International-South Asia, New Delhi, India.

WISA, 2011. Integrated management planning for conservation and wise use of Lake Chilika, India. Technical Report submitted to Ramsar Convention Secretariat. Wetlands International-South Asia, New Delhi, India.

WISA, 2011. Loktak Newsletter, Volume-VI, Loktak Development Authority and Wetlands International-South Asia, New Delhi, India.

WISA, 2012. Economic Evaluation of Loktak Lake. Project Report, Wetlands International-South Asia, New Delhi, India.

Woodward, R.T. and Wui Y.S. 2001. The economic value of wetland services: a meta-analysis. Ecological Economics 37: 257-70.

4 Coastal and Marine Ecosystems

Lead Authors
E Vivekanandan, Madras Research Centre of Central Marine Fisheries Research Institute, Chennai
P Mukhopadhyay, Department of Economics, Goa University, Goa

Contents

1. Overview of the extent and status of coastal and marine ecosystems in India

Coastal and marine ecosystems are among the most productive ecosystems in the world and provide many services to human society and are of great economic value (UNEP 2006). The services include provisioning of food and water resources, and supporting functions such as climate regulation, water balance, flood control, waste management etc. Wetlands recharge freshwater aquifers, prevent erosion and buffer land from storms. The best available data suggest that substantial positive economic values can be attached to many of the marketed and non-marketed services provided by coastal and marine systems (UNEP 2011a). According to some estimates, the oceans and coastal biomes may provide as much as two-thirds of the ecosystem services that make up the planet's natural capital (TEEB 2010).

People have been using marine and coastal ecosystems for centuries. In recent years, the oceans have become the dumping grounds for unwanted materials including toxic wastes. Because of the multiple benefits provided by the coastal environment for human health, wealth and well-being, demographic pressures on coastal resources started increasing during the last century. Recent anthropogenic interventions on coastal and marine ecosystems are many. Dredging of water ways, filling or draining of waterways, large quantities of nutrients reaching the coastal waters, industrialization of coastal areas, and fisheries are a few important interventions. Today, the degraded condition of many seas and the overall decline in their diversity and productivity threaten our coastal communities and human well-being. Resources have been depleted and have collapsed due to human pressures and climate change (IPCC 2007), with economic and social consequences for humans. However, the coastal and marine systems suffer from both inadequate knowledge and governance in comparison with our knowledge on terrestrial ecosystems and their services.

Though posing challenges in conservation, marine and coastal ecosystems provide immense opportunities for conservation. Marine and coastal natural resources are, for the most part, renewable. If properly managed, they should provide continuing returns into the future without diminishing their productivity.

The main objectives of this report, therefore, are to prepare a toolkit for valuation of coastal and marine ecosystem services. The report will also seek to achieve the following sub-objectives:

- Provide an overview of the techniques used in valuation of coastal and marine ecosystem services; and values based on desktop study.
- Identify gaps in the valuation of coastal and marine ecosystems and services values and techniques.
- Identify potential applications for valuation studies on coastal and marine ecosystem services.

1.1 Extent of ecosystems in India

The most comprehensive scientific assessment of ecosystem services called the Millennium Ecosystem Assessment (MA) was initiated in 2002. In the context of MA, coastal and marine ecosystems include terrestrial ecosystems (e.g., sand dune systems), areas where freshwater and saltwater mix, nearshore coastal areas, and open ocean marine areas. For MA, the coastal and marine realm has been divided into two major sets of systems: (i) marine fisheries systems and inshore coastal systems; and (ii) coastal communities. Marine systems are defined as waters from the low water mark (50m depth) to the high seas; and coastal systems are <50m depth to the coastline and inland from the coastline to a maximum of 100 km or 50-metre elevation (whichever is closer to the sea). The MA defines the coastal zone as a narrower band of terrestrial area dominated by ocean influences of tides and marine aerosols, and defines a marine area where light penetrates throughout (MA Condition and Trends volume, section 19.1; www.MAweb.org).

Surrounded by the Indian Ocean, Arabian Sea and Bay of Bengal, the peninsular India has a coastline of about 8,100 km spanning nine maritime states and two union territories in the mainland, and two island union territories. The Exclusive Economic Zone (EEZ) extends to 2.02 million km^2 and the continental shelf area to 0.18 million km^2. The Indian coasts support about 30% of the total 1.2 billion human population. Considering the climatic, oceanographic and biological settings, the Indian coast and the adjoining Exclusive Economic Zone (EEZ) may be categorized into six major ecosystems, namely, northwest, southwest and Lakshadweep Island ecosystems in the Arabian Sea; and northeast, southeast and Andaman & Nicobar Island ecosystems in the Bay of Bengal (Fig. 4.1).

Figure 4.1. Six major coastal and marine ecological regions of India

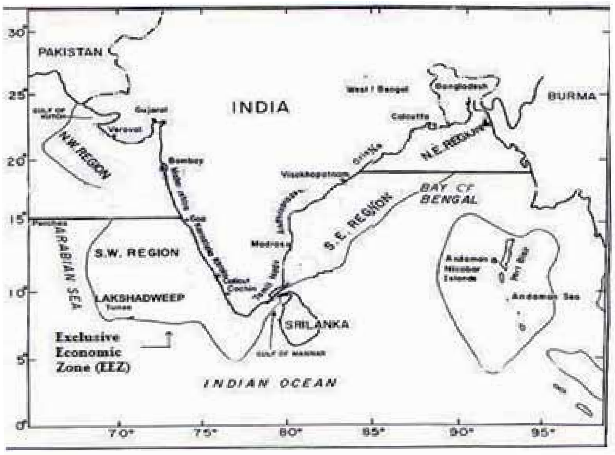


Table 4.1. Extent of coastal ecosystems of India (MoEF 2005)

Coastal ecosystem	Area (km^2)
Tidal/ Mud flats	23,621
Sandy beaches/ bars/ spits	4,210
Mangroves	4,445
Coral reefs	2,375
Estuaries & backwaters	1,711
Salt marshes	1,698
Lagoons	1,564
Other vegetation (including seagrass beds)	1,391
Aquaculture ponds	769
Salt pans	655
Creeks	192
Rocky coasts	177
Total	**42,808**

Indian coastal ecosystems comprising of mudflats, sandy beaches, estuaries, creeks, mangroves, coral reefs, marshes, lagoon, seagrass beds, and sandy and rocky beaches extend to 42,808 km^2 (Table 4.1). They are known for their high biological productivity, which provide a wide range of habitat for many aquatic flora and fauna. The number of species in the coastal and marine ecosystems is suggested to be more than 13,000 (Venkataraman and Wafar 2005; MoEF 2009). However, this is an underestimate considering the fact that the inventory is extensive in the case of commercially important resources, but incomplete for minor phyla and microbes. The species richness of well-surveyed groups include: marine algae - 844 species; sponges - 451 species; hard corals - 218 species; polychaetes - 250 species; crustaceans - 2,934(+) species (Copepoda - 1,925; Cirripeds - 104; Amphipoda - 139; Brachyura - 705; Prawns - 243; Stomatopoda - 121; Cladocera - 3; Ostracoda - 120; Anomura - 162; Lobsters - 26; Mysids - 3); molluscs - 3370; echinoderms - 765; fishes - 1546; reptiles - 35; mammals - 26.

1.2 Status of ecosystems

People are dependent on the coastal and marine ecosystems and their resources for their survival and livelihood. In spite of their ecological and economic importance and existence of a policy and regulatory framework, India's coastal and marine ecosystems are under increasing threat. The major drivers of change and degradation are mainly anthropogenic. Numerous direct and indirect pressures arising from different types of economic development and associated activities are having adverse impacts on coastal and marine biodiversity across the country. Major anthropogenic direct drivers of ecosystem degradation and destruction include habitat conversion to other forms of land use, overexploitation of species and associated destructive harvesting practices, spread of invasive alien species, and the impacts of pollution from agricultural, domestic and industrial effluents. Examples of few anthropogenic pressures are given below:

(i) The coastline of Bay of Bengal and Arabian Sea continues to be rich fishing grounds and India is one of the world's largest marine production nations. Marine fish landings in India has increased consistently in the last 60 years due to expansion of fishing fleet and increase in fishing efficiency. Expansion of fleet and new fishing grounds has helped increase the catches, but overexploitation of few stocks are evident (Srinath *et al.* 2004). Vivekanandan *et al* (2005) detected fishing down marine food web at the rate of 0.04 trophic level per decade in the Indian seas and cautioned fishery-driven changes in the structure and function of ecosystems in the Bay of Bengal and Arabian Sea.

(ii) Increased nutrient loading from agricultural runoff, sewage and fossil fuel burning is causing widespread eutrophication of coastal and marine ecosystems. UNEP (2006) report has indicated that the estimated total reactive nitrogen entering the coastal and marine ecosystems of India increased from 100-250 mg N/km^2/year in the year 1860 to 500-750 mg N/km^2/year in the early 1990s; and this is projected to increase further to about 1000 mg N/km^2/year by the year 2050.

(iii) Evidences are accumulating that climate change is having a growing impact on coastal and marine ecosystems due to increase in extreme weather events, sea level rise, warming of sea surface temperatures and ocean acidification. An extract from the publication of Vivekanandan (2011) shows that (a) the sea surface temperature has increased by 0.2 to 0.3^o C along the Indian coast in the last 45 years, and is projected to increase by 2.0 to 3.5^o C by 2099. (b) The projected sea level rise is 30 cm in 50 years. (c) During the southwest monsoon, the wind speed and coastal upwelling have strengthened, resulting in higher concentration of chlorophyll a along the Kerala coast. These changes are likely to influence the structure and function of marine ecosystems, on which evidences are accumulating. (d) The phytoplankton grow faster at elevated temperature, but the decay sets-in earlier. (e) Species response to elevated temperature is different, showing changes in composition and abundance at the base of the food web. (f) Coral bleaching is likely to be an annual event in the future and model shows that reefs would soon start to decline and become remnant between 2050 and 2060. (g) Mangroves in tropical regions are extremely sensitive to global warming and the extent and composition of mangroves may undergo major changes. Elevated temperature and changes in precipitation and aridity are likely to change the flowering of mangroves. (h) Occurrence of harmful algal blooms seems to have become more frequent, intense and widespread and cause considerable mortality of fish. (i) Among marine fish, the more mobile species should be able to adjust their ranges over time, but less mobile and sedentary species may not. Depending on the species, the area it occupies may expand, shrink or be relocated. This will induce increases, decreases and shifts in the distribution of marine fish, with some areas benefiting while others lose. The distributional and phenological changes may have impact on nature and value of fisheries. If small-sized, low value fish species with rapid turnover of generations are able to cope up with changing climate, they may replace large-sized high value species, which are already showing declining trends due to fishing and other non-climatic factors. Such distributional changes would lead to novel mixes of organisms in a region, leaving species to adjust to new prey, predators, parasites, diseases and competitors, and result in considerable changes in ecosystem structure and function.

(iv) Coastal habitats are also subject to powerful natural weather phenomena, such as tsunami, cyclones, hurricanes and storms.

(v) Indirect drivers of ecosystem change include demographic, socio-political, cultural, economic and technological factors.

1.3 Consolidation of available knowledge and bridging knowledge gaps in India

In a recent report of the Working Group on Ecosystem Resilience, Biodiversity and Sustainable Livelihoods for the XII Five Year Plan, the Planning Commission has consolidated the available knowledge on coastal and marine ecosystems in India and the ways for bridging the knowledge gaps. Salient findings of the Working Group are given below:

1.3.1 Identification of ecosystems of significant marine biodiversity (Planning Commission 2011)

The first step to value marine and coastal ecosystems would be to identify areas of significant marine biodiversity in India, classify them on the basis of research and conservation/ management requirements, record the threats they face, and undertake long-term surveys to document species diversity and trends in populations. The first requirement of such an exercise would be a systematic and exhaustive literature survey followed by a GIS-based mapping of available marine habitats and species in India. This large scale exercise should aim to identify gaps with respect to species, taxonomic groups and sites. The study would facilitate identification of sites in mainland India and help in prioritising sites in the two island systems as well.

1.3.2 Research requirements (Planning Commission 2011)

India has generated extensive checklists of marine species and some amount of information on their distribution and status. Coastal and marine biodiversity and ecosystem research in India has also moved into bar-coding of species and is collaborating in large global projects such as the Census of Marine Life that aims at documenting marine biodiversity. Though these are important baselines, these documents and bar-codes are of little value in undertaking conservation/ management actions. To address the issue of marine biodiversity and ecosystem valuation and conservation, we require a thorough understanding of not only the species richness in a given area, but also of the ecological and ecosystem processes that lead to the observed patterns in diversity. However, such an integrated approach to research on marine biodiversity and ecosystems is generally lacking in India. Research under this theme should focus on the biogeography of marine organisms, ecosystem linkages, and resilience and resistance of species in ecosystems. Conservation and sustainable use of biodiversity requires accurate data in space and time on species occurrence, population trends of species, annual harvest and trade of commercial species, habitat details water pollution etc. For coastal and marine areas, databases and systems developed by the Central Marine Fisheries Research Institute, Indian National Centre for Ocean Information Services, Indian Ocean Census of Marine Life, National Institute of Oceanography, Centre for Marine Living Resources and Ecology and National Institute of Ocean Technology may be used.

1.4 Management of resources

Coastal and marine ecosystems are inseparably linked to the activities on land. Hence, conservation strategies should consider a holistic approach, examining agricultural, industrial and other activities on land whose impacts flow to the rivers and coastal waters and oceans (MARES 2009). For conserving and managing coastal and marine resources and ecosystems, various legislations and acts exist in India (Table 4.2).

Table 4.2. Legislations and acts related to coastal and marine ecosystems

Name	Salient features
Indian Ports Act, 1908	Enactment relating to ports and port charges. Provides for rules for the safety of shipping and conservation of ports
Coast Guard Act, 1950	Provides levying of heavy penalties for the pollution of port waters In 1993, Coast Guard under Ministry of Defence, made directly responsible for combating marine pollution. National Oil Spill Disaster Contingency Plan, formulated in 1996, under Coast Guard Act lays down action to be taken in the event of oil spills
Merchant Shipping Act, 1958	Control of pollution from ships and off-shore platforms
Wildlife Protection Act, 1972	Offers protection to marine biota. Amended in 1991 to prohibit fishing within the sanctuary area in Gahirmatha, the annual mass nesting place for olive ridley turtle, an endangered species; accorded the status of marine sanctuary in 1997. Amended in 2001 to include several species of fish, marine mammals, corals, sea cucumbers and sea shells in Schedule I and III whale shark placed in Schedule I
Water (Prevention and Control of Pollution) Act	Control pollution from land-based sources and has jurisdiction upto 5 km in the sea
Maritime Zones Act, 1976	Describes various zones such as territorial waters, EEZ, Continental shelf etc
Forest Conservation Act, 1980	Includes protection to marine biodiversity
Marine Fishing Regulation Acts, 1981	Aims at sustainable fisheries; implementation initiated by all maritime states and UTs from different years since 1981

Coastal Pollution Control Series, 1982	Aims at assessing the pollution status of coastal waters
Environment Protection Act, 1986	Under this, the Coastal Regulation Zone 1991 has been notified. Standards for discharging effluents are listed
	Regulations on various activities in coastal zone.Classifies coastal zone into four categories specifying activities permitted and prohibited in each category. Offers protection to backwaters and estuaries. Aquaculture was allowed as foreshore activity. In 1996, the Supreme Court banned all aquaculture activities, except traditional and modified traditional, in the coastal zone upto 500m in most places. Aquaculture Authority formed
National Environmental Tribunal Act, 1995	Created to award compensation for damages to persons, property and environment arising from any activity involving hazardous substances
Coastal Zone Management Plans, 1996	Provision for all coastal states to prepare CZMPs
The Biological Diversity Act, 2002	Protect and conserve biodiversity and sustainable use of its components

In addition, India is a signatory to a number of international conventions on biodiversity and ecology such as the UNCLoS and CBD, which include management of marine and coastal ecosystems. India is also a signatory to several international fisheries management instruments such as Ecosystem approach to Fisheries (FAO) and the Indian Ocean Tuna Commission. These commitments have impact on India's management of its natural resources.

Wildlife (Protection) Act, 1972 has listed few coastal and marine species for protection (Table 4.3). The act reviews the status periodically by taking into consideration management measures that are appropriate for marine areas.

Table 4.3. Marine species/groups protected under Wildlife (Protection) Act, 1972

Species/groups	Number
Molluscs (mainly gastropods)	24 species
Whale shark	1 species
Other elasmobranchs	9 species
Grouper fish	1 species
Sea horse	All species
Sea cucumber	All species
Sponges and sea fans	All species
Corals	All species
Turtles	All 5 species
Whales, dolphins & dugong	All 26 species

India has established 31 marine and coastal Protected Areas. The Gulf of Kutch Marine National Park, the Gulf of Mannar National Park and Wandoor Marine National Park are some of the Marine Protected Areas (MPA).

1.5 Understanding economic challenges of changing ecosystems

The four main economic activities in the coastal and marine ecosystems are fisheries and aquaculture, tourism, ports and marine transport, and energy. It is now recognized that future economic development is inextricably linked with environmental and social considerations. This concept is more important in coastal and ocean areas than on land, as linkages among economic sectors, human impacts and all aspects of environmental health are very strong and challenging to manage (IOC 2011). One of the concepts that has emerged in recent years is to develop Green Economy. In its report, IOC (2011) has listed the following key dimensions as the contribution of coastal and marine sectors to the green economy:

(i) protection and restoration of coastal and marine ecosystems and biodiversity, including beyond national jurisdiction; (ii) development of blue carbon markets; (iii) active sea-floor management (including oil, gas and mining); (iv) change in fisheries and aquaculture management regimes toward equitable, non-subsidised and sustainable practices; (v) adaptation to sea level rise and climate change; (vi) integrated coastal zone management; (vii) increasing sustainable use of bio-resources, including biotechnology and bioprospecting; (viii) recognition and adoption of ocean/coastal carbon sinks and create a market for blue carbon trading; (ix) enhanced recycling of major ocean pollutants such as nutrients through market mechanisms; and (x) greater adoption of renewable energy from the ocean.

There are three broad conclusions of the recent UNEP Green Economy study that are relevant to ocean (UNEP 2011b):

a. Greening not only increases wealth over the long term, but also produces a higher rate of GDP growth.
b. There is a clear link between poverty eradication and better protection and restoration of habitat, marine fishery resources and biodiversity.
c. In a transition to a Green Economy, new jobs are created, which over time exceed the losses in jobs in conventional economies.

Moving towards a green economy requires a better understanding of the economic value of coastal and marine ecosystems and biodiversity, as well as contributions of these ecosystem services to societal, cultural and ecological well-being.

2. Prominent examples of the ecosystem types in India

The open seas, coral reefs, mangroves, turtle nesting sites, seagrass beds, salt marshes, mudflats, wetlands, beaches, rocky shores, intertidal habitats, estuaries, deltas and lagoons provide food, water, fuel, recreation, fibre, firewood, habitat, shoreline protection and transportation. They are also important components of nutrients, carbon, water and oxygen cycles.

2.1 Coral Reefs

Coral reefs are shallow water, tropical marine ecosystems, which are characterized by a remarkably high biomass production and a rich fauna and flora. Coral reefs are one of the most productive and complex coastal ecosystems with high biological diversity. The species diversity of coral reefs is perhaps unequaled by any other habitat (www.fao.org/docrep/x5627e/ x5627e06. htm).

2.1.1 Services

The services provided by coral reefs are many. The salient ones are:

- Coral reefs are natural protective barriers against erosion and storm surge.
- The coral animals are highly adapted for capturing plankton from water, thereby capturing nutrients.
- Corals are the largest biogenic calcium carbonate producers.
- They provide substrate for mangroves.
- They provide habitat for a large variety of animals and plants including avifauna.
- They contribute goods and service through tourism.

Reef resources have traditionally been a major source of food for local inhabitants and of major economic value in terms of commercial exploitation. Reefs provide economic security to the communities who live alongside them. In the villages around the Gulf of Mannar, the traditional fishermen have been catching reef fish, diving for pearls, sacred chanks, sea cucumber and sea weeds for centuries. In Lakshadweep, the reefs provide live bait that forms the basis for pole & line fishing for skipjack tuna.

To have an understanding of the human ecology of the coral reef islands, it is important to gain an insight into the relationship between local populations and reef resources. Traditional fishers and people whose livelihood is dependent on the reef perceive reefs as a source of food and revenue. They also perceive the reef as a defense against erosion caused by ocean waves. Mainland communities see reefs as a storehouse of limestone to be extracted for cement and lime industries.

2.1.2 Distribution

In India, major coral reef ecosystems are Gulf of Mannar and Palk Bay (southeast coast), Gulf of Kachchh (northwest coast; which is one of the most northerly reefs in the world; Kelleher *et al.* 1995), Andaman & Nicobar Islands (fringing reefs and a 320 km long barrier reef on the west coast between latitude 10° 26´ N and 13° 40´ N) and Lakshadweep Islands (atolls). The coral reefs in the Indian seas consist of all the three major reef types (atoll, fringing and barrier) and include diverse and extensive reef areas of the Indian Ocean. There are also patches of reef in the inter-tidal areas of the central west coast in Ratnagiri, Malvan and Redi, south of Bombay, Gaveshani Bank and 100 km off Mangalore. Hermatypic corals along the shore are reported from Quilon in Kerala coast to Enayem in Tamilnadu. Corals also occur on the southeast coast between Parangipettai, south of Cuddalore (10°50'N, 79°80'E) and Pondicherry.

The total area of coral reefs in India has been estimated as 2,375 km^2 (Table 4.4). These estimates were calculated from maps developed from IRS LISS II, Landsat TM (bands 2, 3 & 4) and SPOT bands 1, 2 and 3) FCC (DOD & SAC 1997). Recently, the Space Application Centre (SAC), Ahmedabad (SAC 2010) estimated the overall reef area as 3,062.97 km^2, including 521.5 km^2 as lagoons and 157.6 km^2 as coralline shelf interspersed within the system.

Table 4.4. Extent of coral reef area (km^2) in the Indian seas

Category	Gujarat	Tamil Nadu	A & N Islands	Lakshadweep	Total
Reef flat	148.4	64.9	795.7	136.5	1,145.5
Sand over reef	11.8	12.0	73.3	7.3	104.4
Mud over reef	117.1		8.4		125.5
Coralline shelf			45.0	230.9	275.9
Coral heads			17.5	6.8	24.3
Live coral platform				43.3	43.3
Algae	53.8	0.4		0.4	54.6
Seaweeds				0.7	0.7
Seagrass				10.9	10.9
Reef vegetation	112.1	13.3	8.9		134.3
Vegetation over sand	17.0	3.6	10.5	0.4	31.5
Lagoon		0.1		322.8	322.9
Others				101.2	101.2
Total	460.2	94.3	959.3	816.1	2,375.0

The corals in India are from 15 families, 60 genera and >235 species of scleractinian corals from four major reefs of India namely Gulf of Kachchh (45 species, 20 genera; GEC 2010), Lakshadweep (124 species, 34 genera; Jeyabaskaran 2009), Gulf of Mannar and Palk Bay (117 species, 40 genera; Patterson *et al.* 2007). Underwater field mission revealed that the coral reefs of the Andaman Islands are globally significant in terms of diversity. The GOI and UNDP GEF Field Mission reported a total of 235 species of scleractinian (reef building and hermatypic) corals from Andaman group of islands. The Andaman Islands have around 80% of the global coral diversity, suggesting that a final count could reach up to 400 species.

2.1.3 Threats

MoEF (2009) has stated that diverse human activities such as runoff and sedimentation from developmental activities, eutrophication from sewage and agriculture, physical impact of maritime activities, dredging, destructive fishing practices, pollution from industrial sources and oil refineries of anthropogenic disturbances have emerged as threats to the coral reefs. Among natural threats, storms, waves and particularly cyclones are major stresses on corals. The tsunami of 2004 had devastating effect, especially on the corals of Andaman & Nicobar Islands.

Another major challenge for sustainability of coral reefs is warming and acidification of seawater. By establishing relationship between past temperatures and bleaching events, and predicted SST for another 100 years, Vivekanandan *et al* (2009) projected that Indian reefs would soon start to decline in terms of coral cover and appearance. Given the implication that reefs will not be able to sustain catastrophic bleaching events more than three times a decade, reef building corals are likely to disappear as dominant organisms on coral reefs between 2020 and 2040 and the reefs are likely to become remnant between 2030 and 2040 in the Lakshadweep Sea and between 2050 and 2060 in other regions in the Indian seas.

2.1.4 Management

As the reefs were common property, often conflicts in resource use were witnessed. Later, protection of all species of corals under Wildlife (Protection) Act 1972 and declaration of Marine Protected Areas and National Parks (Table 4.5) effectively reduced exploitation of corals. After the implementation of protection measures, the corals reefs are stated to be recovering from their status in the 1960s (MoEF 2009).

Table 4.5. Protection status of coral reef areas

Locality	Status
Gulf of Kachchh	Marine National Park (110 km^2 in 1982)
Gulf of Mannar	Gulf of Mannar Bioreserve
Palk Bay	Collection of coral banned
Andaman Islands	Mahatma Gandhi Marine National Park at Wandoor (234 km^2) and Rani Jhansi Marine National Park at Ritchies Archipelago
Lakshadweep Islands	Collection of corals banned

Coral reef protection and restoration programmes may be initiated in the Indian seas by undertaking the following initiatives (see also Wilkinson 2008):

- There is a continued need to strengthen coral reef monitoring and research in India to reinforce positive recovery trends and rectify particular gaps. Capacity needs strengthening for improving coverage of the vast reef areas in Indian seas. There is also a need for sound data management, analysis and reporting. Broader application of more comprehensive coral reef monitoring approaches, such as the Resilience Assessment methodology developed by the IUCN Climate Change and Coral Reefs Working Group, may be encouraged.
- For protection of coral reefs, Marine Protected Areas (MPAs) have become increasingly prominent. Management of MPAs should be strengthened; management effectiveness has to be reviewed in order to improve management decision making and strategies. The objectives of MPAs are both social and biological, including reef restoration, aesthetics, increased and protected biodiversity, and economic benefits. Conflicts surrounding MPAs involve lack of participation, clashing views and perceptions of effectiveness, and funding.
- Protecting the coral reef resources such as groupers, ornamental fish and crustaceans is essential. Careful management could prevent these from collapsing like many other reef resources elsewhere.
- More genuine and inclusive collaborative approaches in resource management are required. Increased collaboration between government, NGOs, and in particular, the empowerment of communities to participate meaningfully is necessary.

2.2 Mangroves

Mangroves consist of a number of species of trees and shrubs that are adapted to survival in the inter –tidal zone. They are basically land plants growing on sheltered shores, typically on tidal flats, deltas, estuaries, bays, creeks and barrier islands. The best locations are where abundant silt is brought down by rivers or on the backshore of accreting sandy beaches. Their adaptation to salinity stress and to water logged anaerobic mud is high. In size, mangroves range from bushy stands of dwarf mangroves found in Gulf of Kachchh, to 30 m or taller stands found in the Sunderbans.

2.2.1 Services

The mangrove swamps are one of the most productive ecosystems, harbouring a complicated community of animals (Kathiresan 2010). The roots provide a rich substratum for a variety of attached animals, especially barnacles, bivalves and worms. Fish, molluscs and crustaceans find shelter inbetween roots. The branches of trees are evidently habitats of insects, lizards, snakes and birds, including the migratory ones. All the animals depend on the leaves and detritus which when carried by the estuary contribute to the production of organic matter, which is the basic food available to other animals and plants. Plankton and other micro-organisms, which proliferate in the mangroves and the surroundings, are eaten by fishes, prawns, crabs and molluscan larvae. Many of them are commercially important finfish and shellfish. The fertility generated by the mangroves extends to the marine areas. The mangrove forest is also a nursery ground for the juveniles of many important species of finfish and crustaceans. Mangroves for the Future (MFF) has reported that the Indian mangroves support 3985 species that include 919 flora and 3066 fauna. Mangroves play an important role in sediment repository, stabilize shoreline and act as a buffer against storm surges. During cyclones and Asian tsunami 2004, the devastation of coastal areas is reported to be lesser where sufficient mangrove buffers were present.

2.2.2 Distribution

In India, significant mangrove covers are available in Sunderbans (West Bengal), the deltaic regions of Mahanadi of the Bhitarkanika (Orissa), the Krishna and Godavari delta in the Andhra Pradesh, fringing the coast in Andaman and Nicobar islands, on the coral reefs and fringing the mainland in the Gulf of Kachchh, the deltaic regions of Kori creek in Gujarat coast and Pichavarm-Vedaranyam of the Tamil Nadu coast. The mangroves of Sundarbans are the largest single block of tidal holophytic mangroves of the world. The major species of this dense mangrove forest include *Herritiera fames*, *Rhizophora* spp., *Bruguiera* spp., *Ceriops decandra*, *Sonneratia* spp., *Avicennia* spp. and *Nypa fruticans*. The mangroves of Bhitarkanika (Orissa), which is the second largest spread in India, are dense concentration with high genetic diversity. On the west coast of India, mangroves, mostly scrubby and degraded, occur along the intertidal region of estuaries and creeks in Maharashtra, Goa and Karnataka. In Andaman & Nicobar Islands, the small tidal estuaries, neritic inlets and lagoons support a dense, diverse and undisturbed mangrove flora. Compared to the estimate of mangrove spread of the late 1980s (6,740 km^2), the estimate of 4,445 km^2 in the year 2005 shows that the mangroves are fast degrading in the country (MoEF 2005).

2.2.3 Threats

Mangroves provide a life support system and income for people who use them as timber. They are exploited for use as fuel and fodder and the area is converted for coastal development. In general the mangroves are resistant to environmental perturbations and stresses. However, mangrove species are sensitive to excessive siltation or sedimentation, stagnation, surface water impoundment and major oil spills. Salinities high enough to kill mangroves result from reductions in freshwater inflow and alterations in flushing patterns from dams, dredging and bulk heading. Seawalls, bunds and other coastal structures often restrict tidal flow, which is detrimental to the mangroves. It is important to recognize that many of the forces, which detrimentally alter mangroves, have their origin outside the mangrove ecosystem.

Climate change components that affect mangroves include changes in sea-level, high water events, storminess, precipitation, atmospheric CO_2 concentration, ocean circulation patterns, health of functionally linked neighboring ecosystems, as well as human responses to climate change (Ellison and

Stoddard 1991; Clough 1994). Of all the components, relative sea-level rise may be the greatest threat. Sea-level rise submerges the areal roots of the plants, and reduces mangrove sediment surface elevation. Rise in temperature and the direct effects of increased CO_2 levels are likely to increase mangrove productivity, change the timing of flowering and fruiting, and expand the ranges of mangrove species to higher latitudes (Gilman *et al.* 2007). Changes in precipitation and subsequent changes in aridity may affect the distribution of mangroves.

Mangroves in tropical regions are extremely sensitive to global warming because strong temperature dependence of physiological mechanism to temperature places many tropical species near their optimum temperature. The extent and composition of mangroves in India may undergo major changes, depending on the rate of climate change and anthropogenic activities.

2.2.4 Management

To reduce the vulnerability of mangroves and increase resilience, non-climatic stresses such as filling, conversion for other human activities and pollution should be eliminated (Field 1993). To augment mangrove resistance to sea-level rise, activities within the mangrove catchment can be managed to minimize long-term reductions in mangrove sediment elevation, or enhance sediment elevation. Mangrove enhancement (removing stresses that cause their decline) can augment resistance and resilience to climate change, while mangrove restoration (ecological restoration, restoring areas where mangrove habitat previously existed, development of inter-tidal mudflats) can offset anticipated losses from climate change (Field 1993; McLeod and Salm 2006). In India, the large expanse of inter-tidal mudflats (23,621 km^2) may provide a scope of adjustment and adaptation in some areas, mostly in the semi-arid region.

Given uncertainties about future climate change and responses of mangroves and other coastal ecosystems, there is a need to monitor the changes systematically. Outreach and education activities can augment community support for adaptation actions.

The value of mangrove resource in terms of its marketed products can be expressed in economic terms. The "free" services provided by the mangroves are difficult to measure and consequently are often ignored. Since these values are seldom taken into account in the government process, the total value of the mangrove resource is often quite significantly understated. With the purpose of conserving the mangroves, the Coastal Regulation Zone notification (1991) declared total prohibition of developmental activities in the mangrove areas. Afforestation programmes have been initiated in few locations.

2.3 Seagrass beds

Seagrasses are specialised angiosperms that resemble grass in appearance and form dense underwater meadows. They are the only group of higher flowering plants adapted to life in salt water. They occur in shallow nearshore coastal waters upto 8 m depth that are sheltered from high wave energy and in estuaries and lagoons. Seagrasses have key ecological roles in coastal ecosystem and can form extensive meadows supporting high biodiversity. The global species biodiversity is low (< 60 species), but species can have ranges that extend for thousands of kilometers of coastline (Short *et al.* 2007). Major seagrass meadows occur along the southeast coast of Tamil Nadu, in the lagoons of a few Lakshadweep Islands and around Andaman and Nicobar islands. The rich growth of seagrasses along the Gulf of Mannar and Palk Bay coasts and Lakshadweep Islands is mainly due to high salinity, clarity of water and sandy substratum. Seagrasses in India comprise 14 species, dominated by *Cymodocea serrulata, Thalassia hemprichii, Halodule uninervis* and *Halophila* spp.

2.3.1 Services

Seagrass ecosystem provides a sheltered, nutrient rich habitat for diverse flora and fauna. Seagrass beds physically help to reduce wave and current energy, help to filter suspended sediments from water and stabilise bottom sediments to control erosion. They function as stabilizers and sediment accumulators of intertidal and subtidal areas of the coast. They trap nutrients and supply them to the ecosystems. An important phenomenon in seagrass meadows is that they change their own environment, by sediment fixation, or by their capacity to enhance sediment and organic matter trapping (Moriarty and Boon 1989). The habitat complexity within seagrass beds enhances the diversity and abundance of animals. In lagoons wherever seagrass beds are widespread, population of fish and migratory birds is high. Seagrasses on reef flats and near estuaries are nutrient sinks, buffering or filtering nutrient and chemical inputs to the marine environment. They provide a direct source of food for herbivorous animals such as some urchins and fish, green turtles and dugong. The endangered dugong feed exclusively on seagrasses and damage to seagrass beds has direct impact on dugong population. Seagrasses provide nursery and feeding areas for fish, crustaceans, molluscs and other invertebrates, many of which are economically important (e.g., penaeid shrimp, pearl oysters).

2.3.2 Threats

There are several reports of reduction in the spread of seagrass meadows along the Indian coasts. Sridhar *et al* (2010) reported that the seagrass spread in the Palk Bay has reduced (for example, reduction of 785.6 ha area of seagrass meadows in Devipattnam area of Palk Bay) during 1996-2004. Several causes have been attributed for deterioration of seagrass beds. Eutrophication, siltation, trawling, coastal engineering constructions and removal for commercial purposes are the major threats for seagrass beds. Seagrass occurs in shallow water bodies below the low tide line and since water bodies are not brought under regulations, the CRZ notification is ineffective to protect sea grass beds.

2.3.3 Management

In general, seagrass coverage has been observed to remain steady or increase in habitats with relatively pristine environmental conditions, and has declined in areas heavily impacted by overdevelopment of shoreline areas and wetlands. It is important that concerned institutions should actively pursue the goal of managing the seagrass habitats to preserve and restore seagrass coverage to historic levels. Two main focus for improving water quality in the habitats may be addressed to: (i) assist governments in controlling and managing stormwater runoff; and (ii) purchase, and to the extent possible, restore, fringing wetland areas. Water quality for seagrass health has to be improved in the habitats. Improved water quality, over the long-term, is expected to increase the cover and biodiversity within seagrass meadows. Enriching biodiversity within the seagrass meadows will contribute to the economy of the area by enhancing fish stocks, increasing tourism, increasing property values, and potentially creating additional jobs. Outreach and education efforts may be undertaken to improve public awareness and support of seagrass restoration as an effective management strategy.

2.4 Seaweeds

Seaweeds, the larger and visible marine plants, are one of the important sea plants along the Indian coast. They are thalloid plants called algae, which means they have no differentiation of true tissues found in land plants such as roots, stems and leaves. They only have leaf-like appendages. Based on the colour of their pigmentation, seaweeds are broadly classified into different classes and families such as *Cyanophyceae* (bluegreen), *Chlorophyceae* (green), *Phaeophyceae* (brown), *Rhodophyceae* (red) etc. In Indian coast about 770 species of seaweeds are distributed, of this 184 species are green, 166 are brown and 420 are red algae. The maximum of 302 species occur in Gulf of Mannar and Palk Bay (Tamil Nadu), followed by 202 species in Gujarat, 152 in Maharashtra, 89 in Lakshadweep Islands, and 75 in Goa. It is estimated that the total standing stock of seaweeds in India is about 541,340 tonnes (wet weight; Table 4.6) consisting of 6,000 tonnes of agar yielding seaweeds (*Gracilaria* and *Gelidiella*), and 16,000 tonnes of algin yielding seaweeds (*Sargassum* and *Turbinaria*). Extracts of selected seaweed species show antibacterial activity. Iodine yielding seaweed (*Asparagopsis taxiformis*) resources are available in the sub-tidal reefs of Saurashtra coast.

Over-utilization coupled with short supply of seaweeds on one hand, and their loss due to natural calamities like cyclones on the other hand, have prompted cultivation of seaweeds along the Indian coasts. Cultivation conserves the natural resources and improves the elite germplasm. Cultivation technologies for important agarophytes like Gracilaria acerosa and G. edulis, and important carrageenophytes like Hypnea valentiae and Kappaphycus alvarezii have been developed. For the last five years, large-scale cultivation of K. alvarezii has been practiced along Palk Bay in Tamil Nadu coast.

Table 4.6. Standing stock (wet weight in tonnes) of seaweeds in India (modified from Rao and Mantri 2006)

State	Main locality	Standing stock (t)
Gujarat	Gulf of Kachchh	105,720
Maharashtra		20,000
Goa		2,000
Kerala		1,000
Tamil Nadu	Gulf of Mannar	98,120
Andhra Pradesh		7,500
Odisha	Chilika Lake	269,700
Andaman Islands	South Andaman	27,300
Lakshadweep		10,000
Total		541,340

2.4.1 Services

Seaweeds are important as food for humans, feed for animals and fertilizer for plants. Seaweeds are used as drug for goiter treatment, intestinal and stomach disorders. Products like agar-agar and alginates, which are of commercial value, are extracted from seaweeds. By the biodegradation of seaweeds, methane-like economically important gases can be produced in large quantities. Seaweeds are also used as potential indicators of pollution in coastal ecosystem, particularly heavy metal pollution due to their ability to bind and accumulate metals. The seaweed ecosystem provides excellent breeding grounds for marine organisms. Coralline seaweeds provide habitat, refuge and grazing areas for numerous invertebrates and fishes. They form food of herbivorous molluscs and fish. Seaweeds provde three dimensional space in the habitat and provide surfaces for invertebrates to settle and grow, and provide shelters. They modify light penetration, water motion and nutrient recycling, and thereby enhance productivity of the area. Against waves, they provide a dampening effect and thereby shape the environment. They are reported to release chemicals that trigger settlement of invertebrates. They are also effective carbon sequestering agents.

2.4.2 Threats

The major threats to seaweeds are bad water quality, invasive species, overharvest and coastal zone developments. Accumulation of sediments, turbidity, reduction in water clarity; water pollution in the form of chemicals, sewage, fertilizers and nutrient enrichment are threats. Excess removal by herbivores and coastal human populations; reclamation of coastal habitats and shoreline erosion are other threats.

Sea level rise could significantly alter the shape of the coastline and depth distributions near the shore, changing the hydrography of the intertidal and subtidal zones. This in turn would impact seaweed distribution and abundance. In addition, predicted increases in the frequency of storm surges and larger waves could also significantly impact on seaweeds through increased offshore erosion.

2.4.3 Management

Management of seaweeds has received little attention in India. Government actions have been restricted to controlling trade through licensing. Seaweed harvesting is not currently regulated through a specific licensing or permit system. Code of Conduct for environmentally sustainable harvesting of seaweeds needs to be developed and implemented. Sustainable utilization includes conservation efforts to develop seaweed farming and conservation efforts. Associated fauna inadvertently collected with the target species should be returned to the harvested area. Damage and disturbance to the surrounding environment should be minimized. Timetables for commercial harvest of economically important seaweeds based on maturity of the plants should be followed, which may improve sustainability. Several countries have enacted legislation to regulate the harvest.

2.5 Geomorphological coastal ecosystems

The geology of coastal environments provides the underpinning framework on which biological ecosystems exist and interact. Strategic valuation and planning of coastal and marine ecosystems must accommodate a diverse shoreline consisting of a wide variety of marine, coastal landforms and associated geomorphological types (Robbins 1998). Within each of these environments, ecological processes differ, as do the services and anthropogenic impairments. The complex coastal landscapes can be divided into several broad geomorphic systems such as river deltas (fluvial), estuaries, backwaters and lagoons (tidal), beaches (waves), mudflats (tidal and waves), rocky (limited sediment). Each of these systems can be subdivided into distinct coastal landforms that reflect local patterns of sediment accumulation and erosion. The landforms are sand dunes, earth cliffs, sand bars, salt marshes etc (Table 4.7).

Table 4.7. Geomorphological ecosystems of importance (see also MoEF 2005)

Ecosystem	Characteristics	Services	Threats	Management approach
Beaches	Dynamic landforms subjected to erosion/ accretion	Buffer against land erosion; habitats for fauna & flora; turtle nesting; energy base for invertebrates, fish and birds; tourism	Urbanization; industrialization, construction of ports, wharfs, sand mining, dredging	Setback line for coastal constructions; restrictions on dredging & sand mining
Sand dunes	Derived from marine sand delivered to the beach by waves	Sand reserve for coastal protection & stability; helps recharge of freshwater aquifer in coastal areas; habitat for plants and animals	Sand mining; leveling for constructions; unplanned tourism	Setback line for coastal constructions; restrictions on dredging & sand mining
Earth cliffs	Instability and rapid changes due to sea erosion, groundwater, soil binding	Barrier against strong winds and cyclones; establishment of resorts, agriculture	Urban use	Regulations on usage
Rocky cliffs	Composed of hard materials such as sandstone, limestone, granite	Natural barrier against storms; support distinct vegetation; tourism	Mining for minerals	Regulations on usage
Estuaries	Two way flow and mixing of water; tidal range determines the estuarine processes; high productivity	Fisheries value; nutrient transport; spawning, nursery and feeding ground; bivalve beds, site for mangroves; controls salinity and coastal stability by absorbing waves and floods, cleans pollutants by flushing, aquafarming, transportation, saltpans, tourism	Reclamation, pollution, reduction of freshwater discharge from dams, formation of sandbars and siltation restrict entry of tidal water; barriers like dams obstruct migration of fish; overfishing	Control reclamation and release of untreated wastewater discharge; ensure tidal exchange; zonation of users to avoid conflicts
Lagoons	Shallow water body, separated by barriers of sand, but with openings to the sea	Highly productive; migration of species to feed and breed; nursery ground; rich faunal and floral diversity; high detrital composition; ensures coastal stability by absorbing waves and floods, aquaculture site	Reclamation, pollution, reduction in freshwater discharge from dams, dredging	Control reclamation and release of untreated wastewater discharge; ensure tidal exchange; zonation of users to avoid conflicts

Ecosystem	Characteristics	Services	Threats	Management approach
Deltaic areas	Piling up of carried sediments from rivers at the river mouth	Fertile soil, highly productive, large agricultural settlements, barriers to tide & wave actions, sites for mangroves, human settlements	Reclamation, flooding	Zonation of multiple users, ensure sufficient drainage and tidal flow
Salt marshes	Natural or semi-natural halophytic grassland on the alluvial sediment bordering saline waterbodies	Very productive; source of minerals and plant materials, detritus contribute to fertility	Pollution; reclamation	Control reclamation and release of untreated wastewater discharge
Islands	Two major island chains, Lakshadweep (coral atolls; 36 islands, 10 inhabited) and Andaman & Nicobar (mostly forests & hills; 325 islands, 38 inhabited)	Rich and unique biodiversity, tourism and fisheries are of importance	Pollution, reclamation, human settlements	Integrated Coastal Zone Management approach

2.5.1 Mudflats

Mudflats, also known as tidal flats, are coastal wetlands that form when mud is deposited by tides or rivers. They are found in sheltered areas such as bays, lagoons and estuaries. Mudflats may be viewed geologically as exposed layers of bay mud, resulting from deposition of estuarine silts, clays and marine animal detritus. The tidal flats have typical tripartition, namely, supratidal, intertidal and subtidal zones. Most of the sediments in a mudflat is within the intertidal zone, and thus the flat is submerged and exposed approximately twice daily. Great Rann of Kutch (18,000 km^2) and Little Rann (5,100 km^2) in Gujarat are large and typical tidal flats in India. In the past tidal flats were considered unhealthy, economically unimportant areas and were often dredged and developed into agricultural land. Even now, most mudflats in India are listed as wastelands in revenue records. According to the Indian Naval Hydrographic Department's data, the mainland coast consists of 46% mudflats, 43% sandy beaches and 11% rocky coast including cliffs.

Tidal flats, along with intertidal salt marshes and mangrove forests act as flood plains, controlling floods. In areas where the mudflats are deep and stable, salt marshes and mangrove swamps are formed, which are important biologically. They usually support a large population of wildlife, although levels of biodiversity are not particularly high. They are of vital importance to migratory birds, as well as certain species of crabs, molluscs and fish. The soft sediments are a vital part of the coastal ecosystem and provide a number of ecosystem services, namely, primary and secondary production, nursery and habitat for finfish and shellfish, and interception and uptake of nutrients and contaminants from watershed drainage. The maintenance of mudflats is important in preventing coastal erosion.

Intertidal biodiversity is a measure of environmental quality, as sentinel species like bivalves provide a warning of environmental pollution. Seaweeds and several bivalves and crabs in the intertidal areas contribute to the income of dependent human population. The value of intertidal aquaculture is well known. However, mudflats worldwide are under threat from sea level rise, land claims for development, dredging due to shipping purposes, and chemical pollution.

2.5.2 Estuaries

Estuaries, the transitional zones between river and sea, have specific ecological properties and biological composition. They have extremely variable salinity, ranging from 0.5 ppt to 35 ppt. In general, they are very productive and the reasons for high productivity are (ICAR 2011): (i) abundance of autotrophs (phytoplankton, benthic algae and mangroves), which ensures maximum utilization of sunlight for organic production. This organic matter is used as a source of energy by all heterotrophs. (ii) As tidal currents cause turbulence, oxygen content is higher than other natural waterbodies. (iii) Due to rich biological activity of primary consumers (zoo-benthos and zooplankton), the nutrients are rapidly regenerated and conserved. (iv) Large quantities of organic detritus are deposited from surrounding intertidal wetlands. Estuaries are called "nutrient traps" as they conserve large quantities of nutrients from freshwater discharge and land drainage. (v) Several estuaries are bordered by mangroves. It is reported that the mangrove swamps of Sunderbans produce organic detritus of 8 tonnes/ha/year.

The total estuarine and brackishwater area of India is 3.9 million ha and 3.5 million ha, respectively. All the maritime states in the country have major estuarine and backwater systems (Table 4.8).

Table 4.8. Profile of major estuarine systems in India

Estuarine system	Area	Annual flow	Tide	Remarks
Hooghly-Matla (West Bengal)	8,029 km^2	142.6 billion m^3	Highwater elevation: 5.7 m; tidal regime: 200 km	Gangetic delta, the Sunderbans, the world's largest delta and mangrove vegetation; river Ganges deposits 616x10^6 suspended solids
Chilika lake (Odisha)	906-1165 km^2			Mahanadi deposits 10 million tonnes of silt/year
Mahanadi (Odisha)	300 km^2	66,640 million m^3	Tidal regime: 42 km	Rich mangrove canopy
Godavari (Andhra Pradesh)	180 km^2		Tidal regime: 45 km	Coringa mangrove swamp
Krishna (Andhra Pradesh)	320 km^2		Tidal regime: 22 km	
Pulicat lake (Tamil Nadu)	350km^2		Tidal regime: 6 to 10 km	Average depth reduced in last 40 years
Muthupet (Tamil Nadu)	200 km^2			One of the tributaries of river Cauvery
Vembanad lake (Kerala)	250 km^2	10,348 million m^3 during monsoon	Wetland extent: 96 km	Ramsar site
Nethravathi (Karnataka)	11 km^2		Tidal regime: 19 km	
Mandove-Zuari (Goa)	120 km^2			
Narmada (Gujarat)	142 km^2			

2.5.3 Marine Protected Areas

According to the third national report of the MoEF to the CBD in 2006, there are 31 Marine & Coastal Protected Areas, 18 of which are fully under marine environment, and the other 13 are partly also on land (MoEF 2009). These PAs have been notified either as national parks or wildlife sanctuaries, mainly under the Wildlife Protection Act. They cover an area of 6,271km^2, or 4% of the total area under protection. The list of marine protected areas is available in the publications of Singh (2002), Rajagopalan (2008) and Wildlife Institute of India (2008). However, the list is conflicting between these publications. The number of MPAs identified depends on how MPAs are defined.

The Wildlife Protection Act restricts entry into a sanctuary and national park, except certain specified categories, such as those permitted by the Chief Wildlife Warden, or those who have immovable property within the limits of the sanctuary. In the case of a national park, there is no provision to allow the continuance of any right of any person in, or over, any land within its limits. The Act also states that "no person shall destroy, exploit or remove any wildlife from a sanctuary or destroy or damage the habitat of any wild animal or deprive any wild animal or its habitat within such a sanctuary…". On the other hand, biosphere reserves are not legally a PA category, but are an important entity since they are formed by a Central government notification under the UNESCO-MAB programme.

Sanctuaries and national parks are thus primarily no-commercial extractive-use zones, though there are differences between them (Rajagopalan 2008); the highest degree of protection is accorded to national parks where no human interference is permitted, except those beneficial to conservation. In the case of sanctuaries, certain rights may be permitted by the District Collector in consultation with the Chief Wildlife Warden. Thus, while grazing and fishing are completely banned in national parks, in wildlife sanctuaries, grazing and fishing may be regulated, controlled or prohibited. In the case of national parks, the focus is on conserving the habitat of a species, allowing no human activity except tourism, and providing the highest degree of protection. In sanctuaries, the focus is on conservation of a species, with provisions for allowing traditional activities practiced for non-commercial purposes.

In India, the benefits and values of MPAs have not been assessed. There is a need to value and assess the benefits accrued to validate the gains, if any, and to make suitable amendments to the existing and potential MPAs.

3. Ecosystem Services

As mentioned in earlier Sections, coastal and marine ecosystems provide many services to human society, including food and other goods, shoreline protection, water quality maintenance, waste treatment, support of tourism and other cultural benefits, and maintenance of the basic life support systems. Millennium Ecosystem Analysis has conceptualized the ecosystem services framework as (Table 4.9): (i) provisioning services such as supply of food, fuel wood, energy resources, natural products, and bioprospecting; (ii) regulating services, such as shoreline stabilization, flood prevention, storm protection, climate regulation, hydrological services, nutrient regulation, carbon sequestration, detoxification of polluted waters, and waste disposal; (iii) cultural and recreational services such as culture, tourism, and recreation; and (iv) supporting services such as habitat provision, nutrient cycling, primary productivity, and soil formation (UNEP, 2006). These services are of high value not only to local communities living in the coastal zone but also to national economy and trade.

Considering the framework suggested by the MA, the marine and coastal habitats provide at least 16 services to human society (Table 4.10).

Table 4.9. Ecosystem services framework conceptualized by Millennium Ecosystem Analysis

Type of service	Description	Examples
Provisioning	Direct services and consumption goods	Production of food, timber and water
Regulating	Modulates environment	Control of climate, floods, waste, water quality and disease
Cultural and Recreational	Recreational, aesthetic, and spiritual benefits	Religious or tourism services
Supporting	Services that enable the maintenance and delivery of other services, habitat provision	Soil formation, photo-synthesis, nutrient cycles and crop pollination
Other services: “carrying” or “preserving” services, which includes insurance against uncertainty by maintenance of diversity		

Table 4.10. Ecosystem services provided by different coastal and marine habitats (see also UNEP 2006)

Services	Estuaries	Mangroves	Lagoons	Intertidal	Seagrass & Seaweeds	Mudflats	Rocky reefs	Coral reefs	Inshore region	Oceanic
Provisioning services										
Food	√	√	√	√	√	√	√	√	√	√
Fibre, timber, fuel	√	√	√						√	√
Bioprospecting	√	√	√		√				√	
Biological regulations	√	√	√	√	√	√		√		
Regulating services										
Freshwater storage & balance	√									
Climate regulation	√	√							√	√
Human disease control										
Waste processing	√	√	√		√	√		√	√	
Flood & storm protection	√	√	√	√		√	√	√	√	
Erosion control	√	√	√				√	√		
Cultural and Recreational services										
Cultural	√	√	√	√	√	√	√	√	√	
Recreational	√	√	√	√			√	√		
Aesthetics	√	√						√		
Supporting services										
Education & Research	√	√	√	√	√	√	√	√	√	√
Biochemical	√	√						√		
Nutrient recycling	√	√	√	√	√	√	√	√	√	√

3.1 Provisioning Services

Provisioning services are the products people obtain from ecosystems, such as food, fuel, timber, fibre, building materials, medicines, genetic and ornamental resources.

3.1.1 Fisheries

Food provisioning in the form of fisheries catch is one of the most important services derived from all coastal and marine ecosystems. For example, mangroves are important in supporting fisheries due to their function as fish nurseries. Fisheries yields in waters adjacent to mangroves tend to be high. Coral reef-based fisheries are also valuable, as they are an important source of fisheries products for domestic and export markets. Other ecosystems such as rocky intertidal, nearshore mudflats, deltas, seagrass and seaweed beds also provide habitat to fish populations.

In India, marine fisheries contribute to nutritional security, livelihood and income generation to a large population. Marine fish landings in India consistently increased from 0.6 million tonnes (Mt) in 1961 to 3.6 Mt in 2011 (Fig. 4.2). This is different from the global trend, which showed stagnation of marine fish landings at around 90 Mt since 1995 (FAO 2010). Increase in marine fish production in India was possible as fishing extended to new offshore grounds. India has established an extensive infrastructure in marine fisheries and a large population is employed in the marine fisheries sector (Table 4.11). Census 2010 shows that 1.67 million fishermen are employed in the subsistence and industrial fishing sectors of the country.

Figure. 4.2. Estimated marine fish catch along Indian coast during 1961-2011

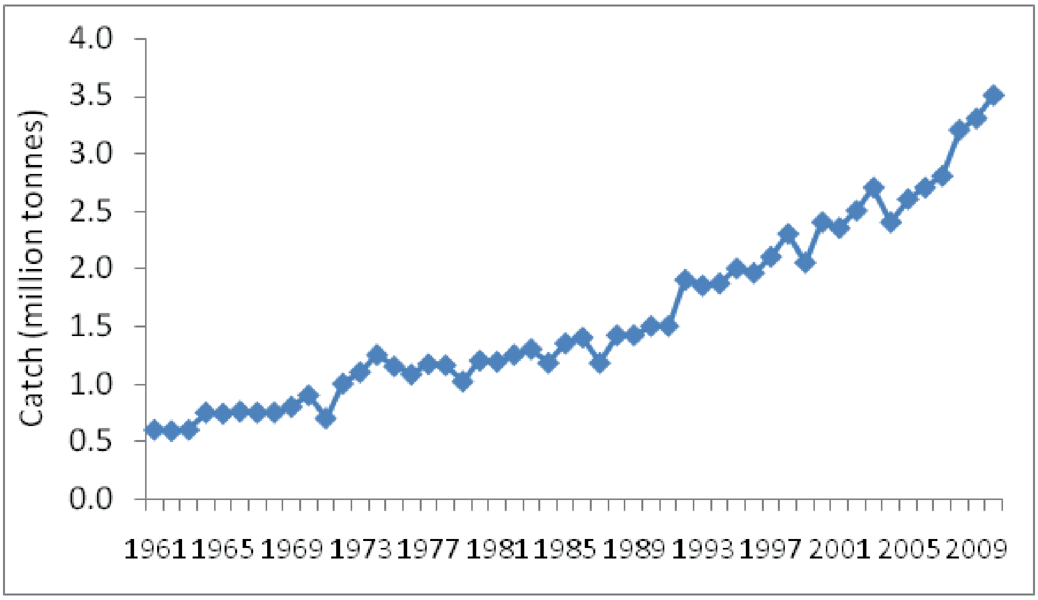


Table 4.11. Profile of Indian marine fisheries in the year 2010 (CMFRI 2012)

Attributes	Number
Marine fishing villages	3,288
Marine fish landing centres	1,511
Marine fishermen households	864,550
Families below poverty line	61%
Fishermen engaged in fishing	990,083
Fishermen engaged in allied activities	675,259
Mechanised boats (inboard engine)	72,559
Motorised boats (outboard engine)	71,313
Non-motorised boats	50,618

The marine fisheries sector witnessed rapid expansion of fishing fleet in the last 50 years. The number of mechanized boats (overall length: 10 to 17 m) with inboard engine increased from 6,708 in the year 1961 to 72,559 in the year 2010; in addition to this, the motorized boats (overall length: 5 to 7 m) with outboard engine, which were introduced in the mid-1980s, increased to 71,313 in the year 2010 (CMFRI 2012). Fishing has thus transformed from a subsistence level to the status of a multicrore industry. However, traditional subsistence fishing, by operating small non-motorised boats, still exists.

In India, the coastal biome (< 100 m depth) produces approximately 80% (in the year 2011) of the marine catches. The coastal biome is also the most impacted by human activities. Besides a source of food and nutrition, germplasm resources are important source of various products of pharamaceutical and commercial value and other trades like ornamental fish. It is recorded that 1,368 species of marine finfish occur in the Indian seas, of which, more than 250 species are food fishes and another 200 are of ornamental value. In addition, about 175 species of crustaceans and molluscs contribute to fisheries in one region or the other along the coast. A bottom trawl haul of one hour, on an average, consists of 40 species of finfish, shellfish and other non-edible biota.

In spite of its importance and increasing catches, the sector faces the following sustainability issues (Vivekanandan 2011): (i) The annual harvestable potential yield from the Indian EEZ is 3.9 mt (DAHDF 2000). As the production (3.6 mt in 2011) is approaching the potential yield, the country has reached a stage in which further increase in production may have to be viewed with caution. It would be difficult to achieve goals related to sustainability if more fish are continuously removed. (ii) The population depending directly on fishing is very great in India and there may not be any quick solution to the problem of overcrowding. At present, only 12% of fishermen are educated at secondary level of school education (CMFRI 2012). Relocating a large number of fishermen with alternate employment is possible only by providing them higher education for highly skilled jobs and improve their societal status. This would be a long-term process. (iii) Fishing has extended to deeper waters as well into new geographical areas. At present, overcapacity is an issue in capital-intensive mechanised fishing sector as well as in the employment-oriented motorised sector. However, the effect of overcapacity of fleet and overfishing of coastal fish populations has been masked by increased landings of additional resources from distant water fishing grounds. (iv) Fishing remains, to a large extent, as regulated open access. In spite of promulgation of Marine Fishing Regulation Acts by maritime state governments, licensing of craft, mesh size regulation, catch declaration, ceiling on number and efficiency of fishing craft, monitoring, control and surveillance of fishing vessels remain as issues. Consequently, entry barriers and capacity controls are ineffective or are absent. The situation exerts fish resources under pressure. The major dilemma is that if access to fisheries resources is restricted, it would affect livelihoods of coastal communities, while if the access is open, the resources will sooner or later decline beyond recovery. (v) The demand for niche seafood products is increasing in international markets. Shark fins and tuna sashimi are some examples. These market-driven fishing activities are changing the face of India from a coastal fishing nation to that of ocean fishing nation. This would exert pressure on oceanic fish stocks, which are highly vulnerable to fishing. (vi) One of the often-ignored factors that causes degradation of environment and depletion of fish stocks is the anthropogenic interference other than fishing. The man-induced alteration of the physical, chemical, biological and radiological integrity of air, water, soil and other media is causing irreversible damage to several fish stocks. (vii) Evidences are accumulating in the Indian seas on the impact of climate change on marine fisheries. Long-term climate change will affect the ocean environment and its capacity to sustain fishery stocks and is likely to exacerbate the stress on marine fish stocks.

The different types of craft use a wide variety of gear types such as trawls, gillnets, seines, lines etc, thereby operating at least 25 major craft-gear combinations. The economics of fishing operation of these combinations differ between each other, which has been monitored from time-to-time for majority of operations (for example, Narayanakumar *et al.* 2009). Similarly, data on the market price of different fish types at landing centres, and at wholesale and retail markets has been collected regularly by Central Marine Fisheries Research Institute (for example, Sathiadhas *et al.* 2011). During 2010, the gross revenue from the catch of 3.2 million tonnes at the point of first sales (landing centre) was estimated as Rs. 19,753 crores (= $ 4.39 billion), and at the point of last sales (retail market) as Rs. 28,511 crores (= $ 6.33 billion) (CMFRI 2011). The estimated gross private investment on fishing equipment (boats) was Rs. 15,496 crores (= $ 3.44 billion). The export of marine products from India was 813,091 tonnes, valued at Rs. 12,901 crores (= $ 2.86 billion) during 2010-11. The sector contributes around 1% to the GDP of the country and 5.8% to the agricultural GDP.

However, the value of fishing and fish price are not the same as the value of fish. In other words, the economic value of a fishing day does not directly address the question of fish resource value. Availability and quality of fish, and the cost of fishing are related to the value of fishing. The value of a particular fish stock or of a prospective change in fish abundance can be estimated in terms of (i) willingness to pay for enhanced fishing opportunities, or (ii) willingness to accept compensation for diminished fishing opportunities.

3.1.2 Aquaculture

Growth in demand for fish as a food source is being met in part by aquaculture. Aquaculture is growing more rapidly than all other animal food-producing sectors. Demands for coastal and brackishwater aquaculture have been on the rise. Brackishwater shrimps *Penaeus monodon* and *Penaeus vannamei*, and the fish *Lates calcarifer* contribute to brackishwater aquaculture in India. The area under shrimp farming is about 100,000 ha (in 2009) and annual shrimp production is 80,000 tonnes. Export has major influence on aquaculture, especially for shrimps. India is one of the leading producers and exporters of shrimps from aquaculture. Farmed shrimps contribute about 42% to the total value of marine products export from the country. However, in the last ten years, shrimp production is stagnant due to issues concerned with viral diseases and environment.

Coastal waters provide the foundation for mariculture. Farming of marine mussels, namely, *Perna viridis* and *P. indica* has become popular among coastal communities of Kerala, Karnataka and Goa, from where about 17,000 tonnes are produced annually. India has the potential for farming of other bivalves such as clams, cockles and pearl oysters; gastropods such as abalone; crustaceans such as sandlobster and rocklobsters. In the last five years, farming of the seaweed *Kappaphycus alvarezii* has become popular among the coastal communities in the Palk Bay and Gulf of Mannar in the southeast coast.

Open sea cage culture has been initiated in the country in the last four years. The high-value Asian seabass *Lates calcarifer*, the cobia *Rachycentron canadum* and silver pompano *Trachinotus blochii* are used as candidates for cage culture. It has the potential to expand in future in the coastal areas of India.

3.1.3 Bioprospecting

Bioprospecting (the exploration of biodiversity for new biological resources of social and economic value) has yielded numerous products derived from species in coastal and marine ecosystems (for example, antibiotics, antifreeze, fibre optics, and antifouling paints). Coral reefs are exceptional reservoirs of natural bioactive products, many of which exhibit structural features not found in terrestrial natural products. Mangrove forests are good reservoirs for medicinal plants. The pharmaceutical industry has discovered several potentially useful substances, such as cytotoxicity (useful for anti-cancer drugs) among sponges, jellyfish and starfish. Cone shells of the molluscan family and sea snake venom are highly prized for their highly variable toxins. This exciting opportunity of bioprospecting is in its infancy in India. CMFRI has recently developed extracts from green mussel and seaweeds, which are reported to relieve pains from arthritis.

3.1.4 Provisioning building materials

Many marine and coastal ecosystems provide coastal communities with construction materials (such as lime for use in mortar and cement) and other building materials from the mining of coral reefs. Mangroves provide coastal and island communities with building materials for boat construction. To discourage exploiting the corals and mangroves for these purposes, the existence of alternative materials should be informed to the communities.

3.2 Regulating services

Regulating services are the benefits people obtain from regulation of ecosystem processes, including air quality maintenance, climate regulation, erosion control, regulation of human diseases, and water purification, among others (UNEP 2006). Ecosystems such as mangroves, seagrass, rocky intertidal, nearshore mudflats, and deltas play a key role in shoreline stabilization, protection from floods and soil erosion, processing pollutants, stabilizing land in the face of changing sea level by trapping sediments, and buffering land from storms (Table 4.10). Mangroves and coral reefs buffer land from waves and storms and prevent beach erosion. Estuaries and marshes prevent beach erosion and filter water of pollutants. Seagrasses play a notable role in trapping sediments (acting as sediment reserves) and stabilizing shorelines.

Marine ecosystems play significant roles in climate regulation. CO_2 is continuously exchanged between the atmosphere and ocean and is then transported to the deep ocean. Mixing of surface and deeper waters is a slow process, allowing increased uptake of CO_2 from the atmosphere over decades to centuries. Phytoplankton fix CO_2 by photosynthesis and return it via respiration. A case study of the Paracas National Reserve, Peru valued carbon sequestration by phytoplankton as $181,124 per year (UNDP 2009).

3.3 Cultural and Recreational services

Cultural services encompass tourism and recreation; aesthetic and spiritual services; traditional knowledge; and educational and research services. Among the most important services provided by the coastal and marine ecosystems are tourism and recreation. Beautiful landscaping, scenic beauty and biodiversity play key roles in promoting tourism along the Indian coasts, especially in the islands. Beaches and estuaries provide numerous recreational opportunities and represent significant economic value. Rapid and uncontrolled tourism growth can be a major cause of ecosystem degradation and destruction, and can lead to loss of cultural diversity. In addition, there are numerous religious and spiritual values that are associated with coastal and marine ecosystems. These relate to both fishing communities as well others who may be not directly involved for their livelihood on these systems such as rituals of birth and death to idol immersion.

3.4 Supporting services

Supporting services include provision of habitats, primary productivity, nutrient cycling, and soil formation.

3.4.1 Provision of habitats

A large number of marine species use coastal areas, especially estuaries, mangroves, coral reefs seaweeds and seagrasses as habitats and nurseries.

Estuaries provide habitat, feeding and breeding grounds for shellfishes and finfishes of commercial and ecological value. They are particularly known for rich bivalve beds and mangrove forests. They are sites of nutrient transport. They control salinity and provide coastal stability by absorbing waves and floods, and clean pollutants by flushing. They support transportation, saltpans, tourism and aquafarms.

The support services provided by mudflats, mangroves, coral reefs, seagrasses and seaweeds are mentioned elsewhere in this chapter.

3.4.2 Primary productivity

Primary productivity is the amount of production of living organic material through photosynthesis by plants, including algae, measured over a period of time. Marine and coastal ecosystems play an important role in photosynthesis and productivity of the systems. Marine plants (phytoplankton) fix CO_2 in the ocean (photosynthesis) and return it via respiration. The primary productivity is the driver that determines the energy flow and biomass of the ecosystems.

3.4.2 Nutrient cycling

One of the most important processes occurring within estuarine environment is the mixing of nutrients from upstream as well as from tidal sources, making estuaries one of the most fertile coastal environments. Mangroves and saltmarshes play a key role together in cycling nutrients. Beaches and sandy shores are important in the delivery of land-based nutrients to the nearshore coastal ecosystem.

3.4.3 Education and research

Marine and coastal ecosystems are areas that have received attention through education and research. Education and research on these ecosystems in India has improved our knowledge on ecosystem dynamics, prey-predator interactions, biological regulations, bioprospecting and fisheries and aquaculture potential. Applied multidisciplinary research on ecosystem function, sustainable yields, and economic valuation of coastal ecosystems is needed. Adequate funding needs to be allocated for education and research on coastal and marine ecosystems.

4. Key issues for conservation of ecosystem services and biodiversity

A number of emerging issues continue to threaten or does not allow rapid progress towards sustainable development of coastal and marine ecosystems. Some of them are:

- Direct dependence of a large poor population on coastal and marine ecosystem services and biodiversity;
- Lack of integration of concerns about ecosystem services and poverty, and the lack of attention on poverty reduction through sound management of ecosystem services;
- Increased nutrient over-enrichment and eutrophication, contributing to pollution, hypoxia and habitat degradation;

- Non-utilisation of ocean-based renewable energy despite proven technological advancements;
- Continuing threats to coral reefs and other major ecosystems from ocean acidification, warming, pollution, habitat loss, and invasive species;
- Barriers to implementation due to other political and administrative priorities, insufficient institutional and scientific understanding of the mechanism and capacity, market issues, lack of financing and unwillingness of stakeholder communities.

5. Current state of art on valuation of ecosystem services and biodiversity

5.1 Global eco-system research: A select summary

The Millennium Ecosystem Analysis provided a framework for classification of ecosystem services, and their relation to human well being. The MA recorded the deterioration of the ecosystem services despite their importance to human wellbeing. It noted that one of the contributing factors for this deterioration was the inadequate use of ecosystem service values in policy decision-making. The TEEB assessment which followed in 2008 was a natural successor of the MA. TEEB made a significant extension of the MA framework by focusing on biodiversity and relating it with ecosystems services (Kumar, 2010).

The literature on ecological philosophy has classified environmental values as (NRC 2004):

(1) instrumental and intrinsic values,

(2) anthropocentric and biocentric (or ecocentric) values, and

(3) utilitarian and deontological values

5.2 Resource valuation methods

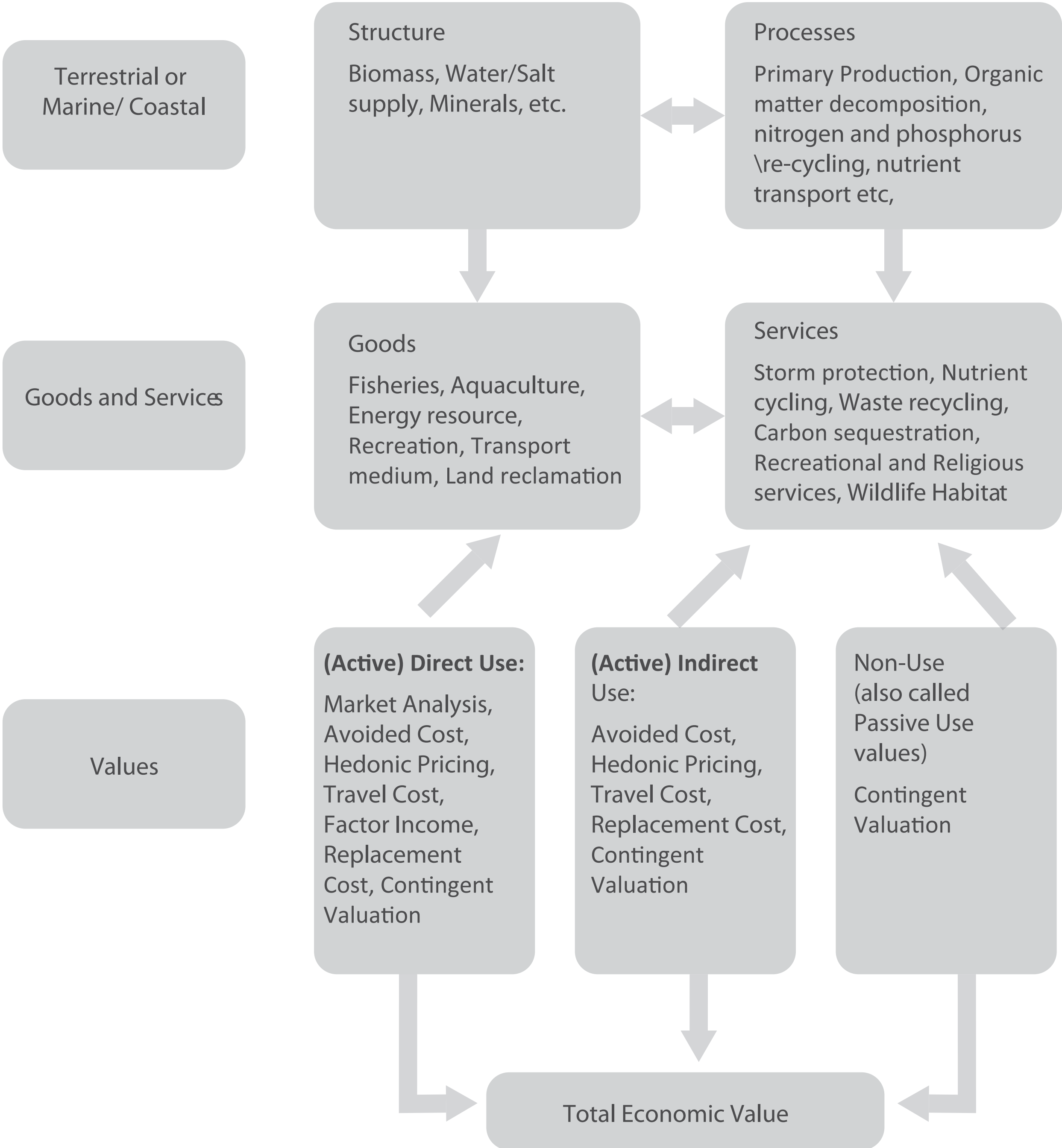
5.2.1 Revealed Preference Method (actual measurements)

Resource valuation is the process of assigning a numeric value, usually monetary, to a natural resource. . There is ongoing debate among economists on how to achieve this but there are two broad schools of thought on the valuation methods in natural resource accounting. One school proposes an ‘energy theory of value’ while the other proposes the standard neoclassical theory of value (Farber *et al.* 2002). The energy theory of value is based on the principles of thermodynamics and considers solar energy as the only “primary” input to the global ecosystem (Georgescu-Roegen, 1971). The intellectual roots of such a proposition in economics can be found in the Smith-Ricardo-Marx-Sraffa tradition which sought to explain true price or value in terms of labour input into a commodity. They considered labour as the “primary” input in production and proposed values that were production-based rather than exchange-based. In addition to the other long standing debated issues with their neo-classical counter-parts, ecological economists have argued that labour cannot be treated as a primary input. It is only energy that is the truly “basic” commodity and scarce factor of production and therefore their argument is that the theory of valuation must be based on the laws of thermodynamics. The problem that arises with this framework is the difficulty in empirical implementation. This is probably one reason why there are fewer empirical studies using the entropy method (Gowdy and Erickson, 2005).

The neoclassical school on the other hand relies on a marginalist framework which is more amenable for empirical enquiry (Pearce 2002). It attempts to value changes in welfare (or some indicator of it) with respect to small changes in environmental resources/attributes (Turner *et al.* 1993). However, the valuation of a resource in the presence of (i) limited information, (ii) thresholds and (iii) irreversibility, needs careful consideration (Dasgupta, 2008).

We will present the major techniques used in ecosystem service valuation and present the Total Economic Value (TEV) framework which has emerged as an over-arching framework for resource valuation (Krutilla and Fisher 1975; Pearce and Turner 1990). The logic of TEV is that resources have multiple “use” (direct and indirect) and “non-use” benefits.

Figure 4.3. Schematic of Valuation Techniques and Ecosystem Services (adapted from Farber et al. 2002)



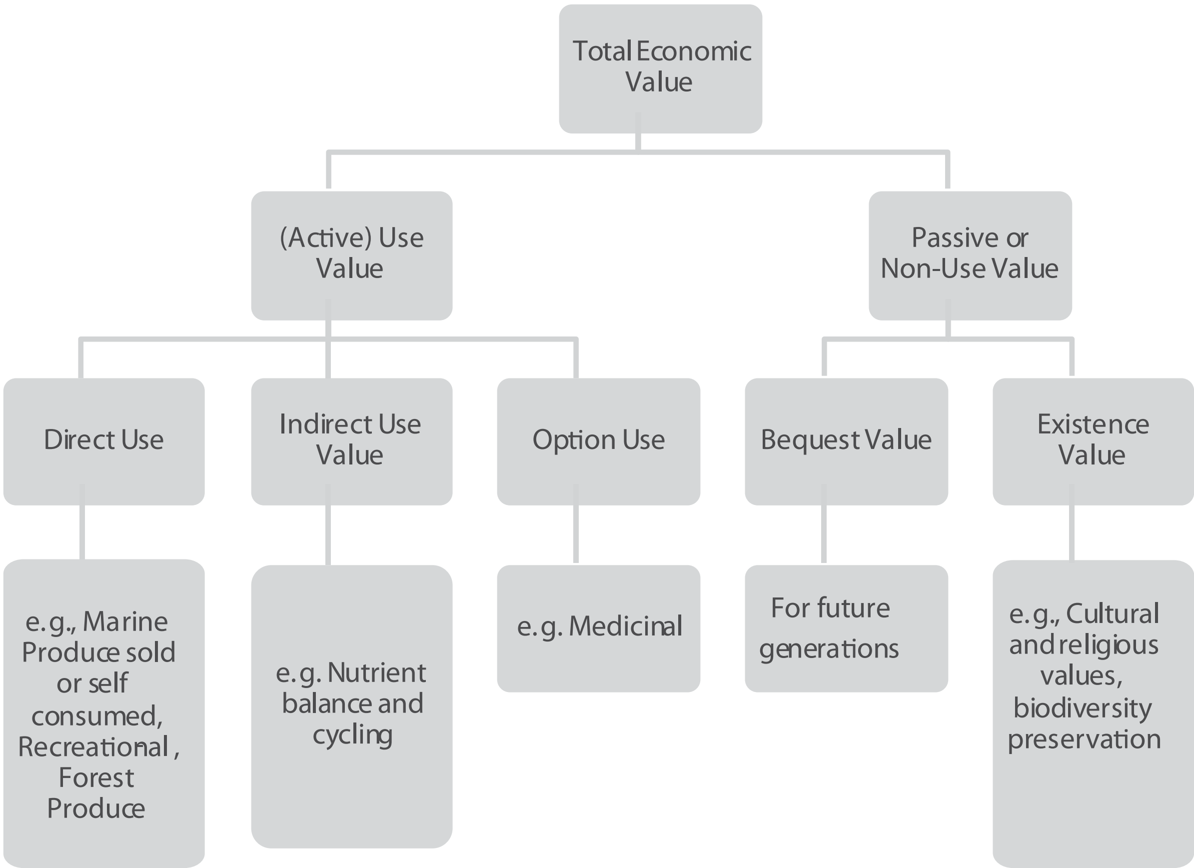
If all these items could be added up then we would arrive at a composite value for one or more natural resources (Fig. 4.3).

Fig. 4.4 provides a schematic for the mechanism to start with the ecosystem and the processes embodied in the system and generate the services.

5.2.2 Market-based valuation methods

Market-based valuation methods rely on market prices to evaluate the flow of resources and also existing stocks. These methods use actual market prices as an indicator of the true value of a resource. Here, willingness-to-pay (WTP) is taken to be equal

Figure 4.4. TEV Schematic diagram (adapted from Beaumont et al. 2006)



to market price. In Gross National Product (GNP) accounting for environmental services, we would include the value obtained from the product of the market price and quantity (Costanza *et al.*, 1997). Since this requires the ecosystem services to have a market price, it implies that this is a service that is traded in the market and refers to a directly used product. Unfortunately, market based approaches do not take us very far as we have pointed out above. Many ecosystem services provide benefits to society but have no direct market and therefore a money value attached to it.

5.2.3 Non-market based methods

A number of methods however allow us to infer values for goods and services that are not directly traded in the market. These non-market methods are classified into two broad categories, namely the revealed preference and the stated preference methods.

The revealed preference methods of valuation are normally considered more reliable than stated preference since it is based on actual observed behavior whereas stated preference methods rely on responses to hypothetical situations. In the earlier applications of stated preference methods there were large differences in estimates. The National Oceanic and Atmospheric Administration (NOAA) deliberated on these methods and provided guidelines of "good practice"(Arrow and Solow 1993). Techniques in both categories have steadily improved and recent studies show that revealed preference estimates could be in the near vicinity of values of stated preference estimates.

Revealed preference methods attempt to value a resource using one or more of the following techniques (Table 4.12):

Table 4.12: Typology of non-market valuation (adapted from Freeman 2003)

	Revealed Preference	Stated Preference
Direct	• Competitive market prices	• Contingent valuation
Indirect	• Production function • Travel cost method • Hedonic models • Avoided cost • Replacement cost • Factor incomes	• Contingent valuation • Contingent choice • Conjoint analysis

Production function approaches use ecosystem services as an input and relate changes in the output to a change in the quality or quantity of ecosystem goods and services of a marketed good or service. This provides an indirect mechanism to value the input by examining its impact on a marketable output. In studies of pollution, this is also called a dose response function.

Surrogate market approaches typically take the form of travel costs and hedonic pricing.

Travel Cost (TC): This technique infers an individual's willingness to pay for a natural resource from the amount that the individual spends on visiting a location.

Hedonic Pricing (HP): This technique examines the willingness to pay for an ecosystem service by examining the differences in prices in a simulated market for natural resources. The housing market with differential location features provides for an oft used application of the Hedonic Pricing method.

Apart from these, we have the cost-based approaches which include replacement costs, mitigative or avertive expenditures and avoided damage costs.

Avoided Cost (AC): The presence of various natural assets allow society to avoid the incurring of various costs – like storm protection and reduced flooding (life and property damage reduction), climate control (reduced energy consumption), health, etc. So, it can be inferred that households would be willing to pay this amount for services rendered.

Replacement Cost (RC): Some natural ecosystem services can be provided by man-made capital or by regeneration the natural capital in case it is degraded. The cost thereby incurred is called Replacement Cost.

Factor Income (FI): This largely belongs to the domain of provisional and recreational services which provide for the enhancement of incomes; for example, improvement in forest quality improves incomes from NTFPs, fishers gain from water quality improvements.

The stated preference methods provide respondents with hypothetical scenarios of environmental quality and seek their responses on them. Contingent valuation is the most popular of these techniques. Respondents are asked their willingness to pay for hypothesized improvement in environmental quality. The Contingent choice models are similar to Contingent valuation except that they do not ask the respondent to place a monetary value to the resource directly. They rely on responses to choices between different states of nature which may or may not have a monetary value associated with them. Sometimes, these models can be used to rank choices. The Conjoint analysis method is more popular among psychologists and marketing research but has also been applied to ecosystem valuation (Farber and Griner 2000). It presents people a set of hypothetical scenarios with multiple levels of attributes. Respondents are asked to choose, rate, or rank among them. Based on the choices they make, analysts derive the structure of their preferences.

5.2.4 Value (or Benefit) Transfer Approach

Apart from the methods discussed above which are used for onsite valuation, the value transfer method is also widely used. This is a technique used to generate estimates for ecosystem services when it is difficult (either due to financial or time constraints) to undertake a specific local area study. It is the second best strategy in the absence of a first best primary valuation study.

As the term implies, value transfer adapts existing value estimates from other contexts dispensing with the need for new data generation. The existing estimates may be taken from a single study but it is often recommended that a sensitivity analysis be done after a meta-analysis of existing studies. The greater the number of similarly located studies available to the researcher, the better would be the accuracy of the estimates from a Value transfer study. The increasing use of GIS information allows better adaptation of values from one context to the other (Beaumont *et al.*, 2006).

Before we discuss some other strengths and weakness of the different techniques we have mentioned above, we would like to highlight the role of discounting in valuation since benefits and costs occur at different periods in time.

5.2.5 Social Discount Rate (SDR)

The debate on SDR has been revived with the discussion on climate change and taken us back a full circle to (Ramsey, 1928). A critical point in this debate has been the choice of a discount rate for comparing temporally separated costs and benefits. Discounting allows us to convert future streams of costs and benefits into present values. However the size of the present value is critically dependent on the size of the discount rate and a small change in it can lead to large differences in NPVs. There are two kinds of discounting that are common – utility discounting and consumption discounting (Heal, 2004).

The Utility discount rate is called by many different names – the discount rate, the pure rate of time preference, the social rate of discount, and the social rate of time preference .

If there is a compelling reason to value the future generations utility less than the present generations, then a positive utility discount rate should be chosen, otherwise this rate should be zero (when society weighs future generations equally as the present).

The consumption discount rate on the other hand measures the value of increasing consumption (as opposed to utility) of one generation with respect to the future. It is not unethical to argue that if in future (due to growth and rising incomes) consumption will be higher, then we should give greater weight to consumption at present (favour the inter-temporally poor vis-à-vis the rich), then the consumption discount rate should be positive. It is also possible that this rate can be negative if there is going to be a fall in the consumption goods (like ecosystem services) in the future – implying the need for sustainable use, by reducing consumption now to save for the future.

The question that remains is whether the utility discount rate should be used or the consumption discount rate. In the partial framework analysis, where the overall social utility is unaffected by the perturbation caused by a project, the consumption discount rate is recommended whereas if the perturbation is of a scale where the future utility would be affected (general equilibrium framework) then the utility discount rate should be used (NRC, 2004).

The literature tells us that the value of the discount rate is ultimately an ethical choice combined with some facts (Dasgupta, 2008). It turns out that the social discount rate is dependent on two ethical parameters – the pure rate of time preference and the value of consumption elasticity of marginal utility and one factual parameter – the growth rate in consumption.

The Ramsey (1928) equation is stated as:
$r = \rho + \theta g$
where r = Discount Rate, ρ = Rate of time preference, θ = elasticity of marginal utility (also called felicity); and g = growth rate of consumption.

If we assume that there is only one kind of commodity – consumption goods, then "r" becomes the consumption discount rate. Therefore, for society to give up one unit of consumption today it would demand (1+r) units of consumptions goods in the next period. There are two ways of approaching the value of "r". The descriptive one "r" and "g" are inferred either from market information or from experiments and then a set of combinations of "ρ" and "θ" would be compatible.

The prescriptive method on the other hand proceeds by assuming a value for "ρ" and "θ". Then "r" becomes dependent on "g". Here the choice of "ρ" and "θ" are ethical choices (for a detailed discussion, see Dasgupta 2008). There is a fair bit of variation in discount rates used in empirical analysis around the world (see for example, H M Treasury 2011; Mukhopadhyay and Kadekodi 2011).

5.3 Global status of valuation

5.3.1 Global Valuation Estimates

One of the most discussed attempts to value the world's ecosystem services placed the value at about $ 33 trillion annually (range: $ 16–54 trillion), estimated to be nearly twice the global GNP of around $ 18 trillion at that time (Costanza *et al.*, 1997). Seventeen types of ecosystem services were valued and the authors distinguished between marine and terrestrial systems. The marine systems had sub-categories of open ocean and coastal, which included estuaries, seagrass/algae beds, coral reefs, and shelf systems (Costanza *et al.* 1997). They found that the bulk of the world's ecosystem services (about 63%) came from marine systems amounting to $ 20.9 trillion per year of which the coastal systems contributed about $ 10.6 trillion per year. Though there were numerous questions raised about these estimates, the paper generated a large amount of academic as well as policy interest (see for example Nature 1998). Another attempt by Pimentel *et al.* (1997) placed the global value of ecosystem services much lower at $2.9 trillion (which was 11% of the world GNP).

These two are representative of the wide range of values that seem to emerge not only from global but also local valuation exercises.

5.3.2 Marine and coastal valuation

Coastal and marine resource valuation studies use methods developed for the broad spectrum of natural resource valuation which accounts for use and non-use values. Natural resource valuation is different from other normal goods and services since many of these resources do not have readily available market prices – either due to distortions or the absence of markets. Some goods that emerge from nature do have market prices – for example fishery output, non-timber forest produce like fuel wood or honey but their market value only reveals a partial value of the resource (Costanza *et al.* 1997) and therefore results in uninformed policy making and inadequate conservation of the resource. This has implications for sustainability and loss of natural capital stock and could result in lowering human well-being. Valuation of coastal and marine resources pose difficulties not dissimilar to terrestrial systems – most ecosystem services are public or semi-public in nature and the problem of uncertainty and irreversibility requiring estimation with thresholds.

One of the early studies attempting to capture the value of coastal systems using the marginal productivity method was by Farber and Costanza (1987). The annual economic value of five different native species (shrimp, blue crab, oyster, menhaden and muskrat) was estimated by totaling the market value of commercial catch. At 1983 prices, the total value of marginal productivity of wetlands in Terrebonne Parish, Louisiana was $ 37.46 per acre.
A global estimate of coastal and marine ecosystems by Martinez *et al.* (2007) found that the total value of ecosystem services and products provided by the world's coastal ecosystems, including natural (terrestrial and aquatic) and human-transformed ecosystems, added up to $25,783 billion per year.

A recent evaluation of five ecosystem services in the Mediterranean (fisheries production, recreation, climate regulation, erosion control and waste treatment) found the aggregate value of services to be above 26 billion Euros annually. Fisheries services were valued at 3 billion Euros, recreational services were about 17 billion Euros, carbon sequestration at 2.2 billion Euros, protection against coastal erosion at 530 million Euros, and waste assimilation estimated at 2.7 billion Euros, annually (UNEP-WCMC 2011).

Cisneros-Montemayor *et al.* (2010) estimated the global demand for eco-tourism in marine ecosystems from a meta-analysis and found that three activities (whale watching, diving and recreational fishing) generated as much as $ 47 billion in 2003, bulk of this coming from the USA (about $ 30 billion). Similarly, a worldwide review of fisheries in 2006 by FAO estimated the value of high sea fisheries to be €447 million (Armstrong *et al.*, 2010).

The total profit (or loss) from fisheries is measured by total revenues minus total costs. Total subsidies are subtracted from this, as they represent an additional cost to society of the fishing industry. The FAO's estimate of the value of annual global catch in

2004 was around $79 billion. According to the World Bank, the operating costs, including fuel costs, labour costs and other operating costs, totalled around $73 billion, with the total capital costs of the industry estimated at $11 billion. This implies that the industry as a whole made a loss of $5 billion. Taking into account all other subsidies except fuel subsidies, the full economic value of the fishing sector is equal to a cost or loss of US$26 billion (Sumaila and Pauly 2006). A complete understanding of the economics of fisheries must take into account not only the direct revenues and costs of the fishing industry, but also the broader environmental and social costs and benefits that the industry provides. This is necessary in order to provide an estimate of the aggregate 'value to society' that fisheries provide. These represent a cost to society, which is generally not accounted for by the industry's direct revenues and costs. Many of them are also very difficult to assign a monetary value to. This valuation of externalities at the global level is therefore limited to the cost of carbon dioxide emissions from global fisheries, although it is evident that there are other externalities that would represent a negative cost even if they cannot be quantified. Other major externalities are: destruction of coral reefs; unwanted bycatch and discards; and destruction of benthic habitats. The total carbon emissions from global fisheries have a social cost of $5 billion. To account for this, the cost of $5 billion is added to the full economic cost of fisheries of US$26 billion, to get a total cost of US$31 billion (Sumaila 2010).

In spite of these estimates, the number of valuation studies in this domain is comparatively limited. A recent review of ecosystem provisioning services pointed out that even though many studies are now available for terrestrial natural resources, there is a large gap in marine resource valuation (NRC 2006). These include valuation of on-site consumptive and non-consumptive use, as well as off-site non-consumptive services. Even the recent TEEB review points out that "the ecological aspects of marine conservation have been studied, but research into its social and economic dimensions is rare" (TEEB 2012). In recognition of this knowledge gap, there have been a number of initiatives. One such initiative funded by the European Union is a network called MarBEF (www.MarBEF.org). The objective of this network is to bring together knowledge and expertise on marine biodiversity and provide monetary estimates of marine biodiversity.

Within the marine ecosystems, few ecosystem specific studies are also available. The coral reefs form an important ecosystem providing both use and non-use values. Conservation International (2008) compiled the estimates available from different researchers on the ecosystem services available from coral reefs. Total net benefit per year from the world's coral reefs was estimated at $ 29.8 billion of which recreation benefits were $9.6 billion, coastal protection $9.0 billion, fisheries $5.7 billion, and biodiversity $ 5.5 billion (Cesar *et al.* 2003).

Wetlands form a very proximate and important ecosystem that provides multiple services – provisioning, regulatory, supporting as well as recreational and cultural. It is also probably the most studied ecosystem in terms of valuation estimates in the coastal and marine segment. A 2006 meta-analysis of wetlands valuation from around the world found that the average annual value of services is about $2,800 per hectare (Brander *et al.* 2006).

The mangrove systems, like coral reefs, are known as nurseries for fish and shrimp as supporting services. Damage to such mangroves could affect aquatic production. Barbier and Strand (1998) who studied mangrove reduction in Mexico found a reduction in annual shrimp output by more than $150,000 per square kilometer reduction of mangroves during 1980-81.

5.3.3 National estimates

At the country level for the USA, Pimentel *et al.* (1997) estimated ecosystem services to be $ 319 billion. Patterson and Cole (1999) estimated New Zealand's terrestrial ecosystem services from biodiversity and placed the value at NZ $ 44 billion per year (1994) and found it to be about half the size of the GNP. However, they did not include marine ecosystem services and suggested that it might be higher than the terrestrial ecosystem services. A country level estimate of ecosystem services of Scotland placed the value at $ 24 billion (Williams *et al.*, 2003).

5.4 Indian status and potential adaptation of global valuation information and methods to Indian conditions

There have been attempts in India to estimate the value of natural resources. Some of these are macro estimates, for example to calculate the green NNP both by official and non-official agencies. The official estimates are not yet available in the public domain but one non-official initiative from the Green Indian States Trust (GIST) provides a set of estimates of national and sub-national income. They call this the environment-adjusted state domestic product, ESDP. The traditional NNP estimates are adjusted for values of forest resources, agriculture and grazing land values, cattle, known mineral deposits, and surface freshwater at the state level and national level. Unfortunately, GIST did not bring within its ambit marine and coastal ecosystem services. Therefore, this remains a gap in the literature.

However, there is now a growing literature of micro studies that look at either specific sites or services using a multiplicity of techniques discussed above. We list a few studies in India that are linked to coastal and marine ecosystems (Table 4.13).

Table 4.13. Studies on coastal and marine ecosystem services in India

Type of Ecosystem	State	Area	Type of services	Method	Type of goods	Authors
Coral reef	Gujarat	Gulf of Kacchh	Multiple	Mixed	Multiple	Dixit *et al.* (2010); Dixit *et al.* (2012)
Mangroves	Orissa	Bhitarkanika	Provisioning	Market Value	Fisheries and Forestry	Hussain and Badola (2010)
Mangroves	Orissa	Kendrapada	Regulating	Damage reduction function	Reduction in loss of life and property	Das and Vincent (2009); Saudamini Das (2009)
Mangroves	West Bengal	Sunderbans	Provisioning	Travel Cost	Recreational Aspect	Guha and Ghosh(2010)
Mangroves	West Bengal	Sunderbans	Provisioning	Translog Cost Function	Valuation of biodiversity loss	Chopra *et al.* (2010)
Mangroves	West Bengal	Sunderbans	Provisioning	Market value	Contribution of tourism in livelihood	Guha and Ghosh(2007)
Mangroves	Gujarat		TEV	Multiple	Mangrove contribution to livelihood	Hirway and Goswami (2007)
Soil productivity	Gujarat	Olpad Taluk, Surat Dist	Regulating	Damage Cost	Salinity Ingress	Sathyapalan and Iyengar (2007)

5.4.1. Provisioning services

Direct Market Method

Direct market valuation of provisioning services is the least complicated to compute as they have direct market values available.

At a micro-level using the direct market values, Hussain and Badola (2010) provided estimates of livelihood support from mangroves in the Bhitarkanika conservation area in the Odisha coast. They considered only two items of provisioning support from mangroves – fishery and forest products. In order to examine the contribution of mangroves to fishery, they separately valued flows from inshore fishery, offshore fishery, and as nursery ground for fish and shellfish. The price at first sale (local market prices) was used for market valuation. They also considered timber and non-timber extraction from mangroves. An average household derived about

US$ 107 per annum worth of livelihood support per year. In comparison to the average family income in this area of US$ 603 per annum, the dependence on ecosystem services as a livelihood support was found to be significant.

In recreational provision studies it is not common to find estimates of gains in livelihoods (factor incomes) due to tourism in India. Guha and Ghosh (2007) provided a case study of the Indian Sunderbans where they examined the gains in livelihood (from factor incomes) generated by tourism and find that households that engage in tourism are less dependent on forest products.

Chopra *et al* (2010) examined the ecological loss due to biodiversity decline in the Sunderbans driven by over-extraction of shrimp larvae. The biodiversity decline is perpetuated by aquaculture farms which acquire seedlings from the wild and thereby deny the natural ecosystem of the wild shrimp larvae. This decline in shrimp larvae disrupts the ecological balance of higher trophic fishes which feed on shrimps.

5.4.2 Regulatory Services

Even though direct market methods are often used to estimate provisioning services, Sathyapalan and Iyengar (2007) considered the regulating service provided by the coastal zones by way soil salinity prevention to agricultural farms in Gujarat. They examined the differences in agricultural productivity in two areas – one where there is salinity ingress and another where there is no ingress and found that the per acre cost of salinity ingress ranges between Rs. 72,221 to Rs. 98,145 (depending on the discount rate). Their study did not undertake valuation of ecosystem services, but their estimates are an indicator of the value of the regulatory services that nature provides by preventing salinity ingress.

Apart from the application of direct market techniques, there have been some studies that use non-market valuation techniques. A study based in Kendrapada, Orissa on the storm-protection services of mangroves during the Super Cyclone 1999 suggests that mangroves reduced loss of human life, house damage, livestock damage, etc. Their cost-benefit calculations show that it is economically beneficial to reconvert land surface which earlier had been under mangrove cover (Das and Vincent, 2009). If house damage alone is considered, the protection benefit was US $ 1218 per hectare of forests (Das 2009).

5.4.3 Recreational Services

The travel cost method has been applied in India to coastal and marine areas, for example to estimate the recreation value of the Indian Sunderbans which is a UNESCO World Heritage and also a Ramsar site. Guha and Ghosh (2009) used a zonal travel cost method to estimate the annual recreational value to Indian citizens of the Indian segment of the Sundarbans and found that it amounts approximately to $ 377,000 (in the year 2006). Their study suggested that by hiking the entry fees to Sunderbans park, the authorities could raise revenues amounting to US$ 0.12 million per year. This would be useful for improving park maintenance.

5.4.4 Contingent Valuation Method

The CVM has been used in India to capture non-use values despite concerns raised on the reliability of the method. Anoop and Suryaprakash (2008) attempted to calculate the Option Value of Ashtamudi Estuary, a Ramsar site located in Kerala. The ecology of this estuary is under threat from anthropogenic activity. The preservation of the wetland prompted the authors to ask how much people (three categories: fishers, tourists and coir producers) are willing to make a “one time payment …. towards the conservation of the Ashtamudi estuary”. They used a contingent choice technique and found that the option value of the estuary was Rs.3.88 million. They also estimated the present value of the estuary by using a discount rate of 4% and found it to be Rs. 87.1 million.

5.4.5 Multiple Method Valuation studies

Coral Reef Ecosystem

There have been very few attempts to study ecosystem services values of coral reefs in India. Dixit *et al.* (2010, 2012) valued five different kinds of services that emanate from corals - fisheries, recreation, protection of coastal aquifers (against salinity ingression), protection of coastal lands (against erosion) and biodiversity. They used different methods to assess the value of each service. In order to estimate the biodiversity value and protection from coastal erosion, they used the value transfer method. Fishing benefits were calculated by direct market method. Recreation values were estimated indirectly by extrapolating tourist arrivals instead of the more common Travel Cost estimates or stated preference method. The protective role of corals for aquifers and soil erosion was estimated partly using a Benefit transfer method and partly using the preventive expenditure information and crop damage information. They found the value of ecosystem services emanating from coral reefs of Gulf of Kachchh was Rs. 2200.24 million (2007 prices) and Rs. 7.95 million per km^2.

Wetland System

Anoop *et al.* (2008) attempted to value the direct and indirect use benefits from Ashtamudi estuary. Four types of direct use benefits are estimated: fishery, husk retting, inland navigation and recreation. For valuation of recreational benefits, the travel cost method was used while the rest were valued by the direct market value technique. Two indirect benefits were also examined – carbon sequestration and shrimp larvae protection. The value transfer method was used to estimate the indirect benefits. They found the net approximate value of use benefits as Rs. 1924 million.

Mangrove system

In a study based in Gujarat, Hirway and Goswami (2007) attempted to calculate the TEV of mangroves. They found that the direct use value (2003 prices) of mangroves was Rs. 1603 million, and the indirect use value was Rs. 2858 million per year. The total use value (direct and indirect) of mangroves was estimated at 7731.3 million per year (2003 prices).

Marine Protected Area

In recognition of the critical role that coastal and marine ecosystems play in human well-being, Marine Protected Areas (MPAs) have been designated in the world oceans. In a remarkable exercise in the UK, as a part of identifying areas and preparing the bill for MPA notification and enactment, a marine valuation exercise was undertaken and discussed with the public prior to enactment of the MPA Act.

In India, while a lot of conservation efforts have been made to terrestrial protected areas (especially forests), marine protection is yet to see similar efforts. The Coastal Zone Regulation Act provides a degree of protection, but its implementation is not uniform across different states. There is an urgent need to address coastal and marine ecosystem management issues that are beyond the Coastal Zone Management bill, which received a mixed response from the public and different stakeholders. The discussion with stakeholders needs to be based on independent evaluation of the ecosystem services. In India, among the MPAs, valuation work has been done in the Gulf of Kucchh (as we have mentioned earlier).

It is important to note that valuation needs an interdisciplinary approach and the need for bio-economic modeling cannot be over stated when we are dealing with issues of valuation. Empirical examples in India are rare. One such attempt was by Bhat and Bhatta (2006) who estimated sustainability in fisheries but not with the objective of explicit valuation. They argue that increase in mechanisation and access to technology has made it possible for large scale fishing activity but increased fishing effort has made the fish stock in many species unsustainable without substantially improving profitability of the fishers. An extension of such an exercise may allow an estimation of shadow values of fishery services and better management of resources.

Managing the marine and coastal ecosystems requires an understanding of the socio-ecological systems and their inter-connections. We need a way to incorporate our knowledge on thresholds and regime shifts into our policies. Management strategies must complement scientific knowledge of marine and coastal ecosystems with social concerns of distribution, equity and justice.

6. The way TEEB assessment can contribute to the conservation challenges

6.1 Policy implications for capturing the value

Economic valuation becomes necessary when there is scarcity of a resource and there are alternative competing uses of these resources. When society must choose one of many options available, Cost-benefit analysis is the preferred tool but we need values in order to undertake this exercise. In situations where monetary values are difficult to obtain, multi-criteria analysis has emerged as a substitute technique. Natural resource damage assessments in the light of demand for compensation and the need for adjudication by the Courts have also spurred the need for valuation (Nunes *et al.* 2009). On a macro-level too the issues of sustainability have compelled economists to engage with the traditional measures of well-being.

In received development theory, the gross national (or domestic) product (GNP) has been used widely as a measure of well-being as it measures the amount of gross economic activity (and thus employment). However, since growth in GNP could occur by depleting assets it has been argued that GNP could be a misleading indicator as a part of GNP does not represent income but just revenue. Thus, a rise in GNP may be a short-run phenomenon if it is being achieved by depleting the asset base of the economy (Hamilton and Ruta 2006).

This problem is partly overcome when we compute the Net National Product (NNP) which accounts for depletion of fixed capital. But traditional measures of NNP do not incorporate changes in the "natural" capital stock. Receipts from extractive industries like oil and minerals constitute increases in revenue and not income as they are achieved by depleting natural capital. Revenues cannot be treated as income as it gives a false sense of high current well-being. So we need to find a way to adjust the traditional NNP for any depletion of the natural resource base.

To overcome this gap, a System of Integrated Environmental and Economic Accounting (UN *et al.*, 2003) has been developed which extends traditional measures of national income to record changes in the natural resource base and accounts for environmental pollution. This environment-corrected measure is often referred to as the green NNP. The SEEA is known as satellite accounts since it is an addendum to the traditional NNP computation methods. A specialized manual on fisheries, the System of Environmental and Economic Accounting for Fisheries (SEEAF) is already available. Interestingly, the manual takes a system wide approach for fisheries accounting, as fisheries production cannot be examined in isolation from the rest of the marine and coastal ecosystems. It is possible that there already exists adequate sector-wise information for fisheries, tourism, and coastal land use planners. The advantage of putting this information in a national income framework is that these sectors can then perceive inter-sectoral links, and better align their policies to develop their resources.

The debate on sustainability, however, suggests that Green NNP is not a sufficiently reliable measure. The reliable indicator of sustainability is comprehensive "wealth," which is the sum of all forms of capital – physical, human and natural - valued at their shadow prices (Dasgupta and Maler, 2000; Arrow *et al.*, 2004; Dasgupta, 2009). Social preferences in terms of both contemporaneous as well as inter-generational equity would be reflected by the nature of the inter-temporal social welfare function. This would in turn help establish the shadow prices. If the present value of aggregate capital is non-decreasing then one can anticipate that the economy is on a sustainable path.

6.2 Role of policy-based instruments for optimizing the value

State responses to halting environmental degradation can take two possible paths. One set of instruments fall under the category of command and control policies and the other are market based instruments which take the form of taxes and fees. The command and control policies directly mandate the extent of resource use and do not rely on any market mechanism. Taxes and fees on the other hand rely on the existing marketed goods and a levy that at the efficient level should compensate for the resource use or damage.

Theoretically, it is possible to show that both these instruments can lead to similar outcomes. However, when there is risk of great damage from degradation or overuse, command and control policies are preferred to market-based instruments. In the context of ecosystem services, if the ecosystem has reached a state of criticality or if a tax/fee is difficult to implement and monitor, command and control instruments would provide more satisfying outcomes. There are numerous examples of such policies both in India and abroad. For example, a ban on fishing during breeding season, land use zoning, are common command and control measures. Entry fees to wildlife sanctuaries and protected areas, pollution taxes, water cess, garbage tax and royalty fees on mineral extraction form part of a set of market instruments deployed for ecosystem management.

Private responses may also emerge in the absence of state policies. These responses could lead to evolution of social norms and conventions or market creation which may take the form of Payment for Ecosystem Services.

There are numerous examples of social norms being used for ecosystem management. A self- regulated ban on fishing during breeding season have sustained the livelihood of fishing communities; restrictions on non-timber forest product extraction, and efforts to protect biodiversity by creating inviolate spaces like sacred groves, have provided forest communities sustenance.

Bargaining is usually the mechanism for interaction between competing users in the absence of a market. Bargaining could be as local as between two villages sharing a common lagoon for fishing, or in the case of trans-boundary resources as complicated as the International Convention for the Regulation of Whaling or the ongoing climate change negotiation between multiple governments and non-governmental organizations.

6.3 Role of market-based instruments for optimizing the value

Market-based instruments are used quite frequently, and in addition to offering the option of efficient management of ecosystems, also provide much needed revenue for management. Payment for Ecosystem Services (PES) has emerged as a possible mechanism for optimal use of natural resources creating the opportunity for re-generating or conserving a natural resource. PES is an umbrella term which includes schemes that rely on one-off deal between two communities, and more complex 'market' mechanisms involving multiple nations and intricate futures instruments.

PES scheme could involve at least four types of participants:

(i) Public sector agencies who secure ecosystem services for public at large

One of the best known examples of this is the Catskill Mountain scheme for New York's water supply. This watershed delivers about 1.2 billion gallons of drinking water daily to 9 million New Yorkers. It spans nearly 2000 square-miles, 19 reservoirs and aqueducts cutting across nine counties. The water supply of New York is delivered through aqueducts from these mountains for the last two centuries. However, in order to meet the water quality regulations, the city had the option of protecting its watershed and allowing the ecosystem to provide high quality water or to use a modern water filtration plant. The relative cost of the two options was estimated; whereas the modern filtration plant was estimated to cost about \$6 billion (with an annual maintenance cost of \$ 250 million), the ecosystem option was estimated to cost about \$1.5 billion. The city selected the second option wherein they bought over 70,000 acres of land from upstream communities and worked with them to reduce pollution from farm waste run-off. This has not only reduced the cost that the citizens of New York have to bear but also helped upstream communities to improve their well-being substantially due to ecosystem related payments from the city.

(ii) Philanthropists who pay to conserve a resource as an act of altruism

These are agents who are motivated by non-use values. Environmentally conscious citizens and organisations very often contribute money or resources either for specific programmes or to conservation-oriented organisations.

(iii) Private agents (including communities) who undertake private deals to conserve ecosystem

They are motivated by use-values derived from ecosystem services. There are many emerging examples of this.

(iv) Consumers of eco-certified products, which include both use and non-use values

This market has emerged due to increased consumer awareness. A market for eco-products that range from food to various non-food items (including household and construction material) has emerged across the globe. The market in developing countries is still small, but in Europe and the USA this is much larger.

6.4 Implications for corporate decision-making

With increasing public awareness, and environmental legislation, there has been concerted effort by the corporate sector to act more responsibly towards the environment. Some firms have encapsulated these efforts within the ambit of Corporate Social Responsibility. Valuation of natural resources and ecosystem services would help the corporate to plan their activities better. It will also enable them to assess the risks involved in their domain of operation. The World Business Council for Sustainable Development, for example, is actively engaging corporate to make better business decisions incorporating values for ecosystem in their business plans (WBCSD 2011).

These have acquired certain amount of importance following compensation awarded by Courts after a human caused environmental disaster (Carson *et al.*, 2003). The Exxon Valdez oil spill which occurred in Alaska in March, 1989, and the Deepwater Horizon oil spill in April, 2010, are regarded as some of the most devastating human- caused environmental disasters for the marine ecosystem (Martínez *et al.*, 2012). After the oil spill in the Arabian Gulf following the Gulf War 1991, compensation was paid to the affected countries bordering the Arabian Gulf by Iraq through United Nations Compensation Committee. The compensation was adjudicated by the Geneva Court. These developments had significant impact on the legal framework as well as corporate planning.

6.4.1 Marine & coastal spatial planning

Valuation would be of great help in marine and coastal planning in India. It would allow the citizens as well as the government to evaluate alternative proposals for development projects on shore and off shore by weighing their impact on sustainability. It would improve Integrated Coastal Zone Management plans in the country which are sensitive to local needs.

For example, in Goa there has been a long-standing tradition of following a decadal regional plan which attempts a state-wide planning exercise. In its current phase, this Plan involves both micro-planning at the village level which is expected to reflect in the aggregated state level plan. The draft plan 2012 has been prepared in conjunction with local bodies to demarcate zones that are ecologically sensitive (http://www.goa.gov.in/pdf/RPG21.pdf). Village level plans have been created in the spirit of the 73rd and 74th Constitutional amendment developed to accommodate local aspirations in a participatory process. Valuation of resources and ecosystem services would help future planning of this nature.

6.4.2 Bioprospecting - Access and benefit sharing arrangements

The marine and coastal ecosystem has great prospects for bioprospecting. The estimated value of the pharmaceutical industry globally was estimated to be $643 billion (in 2006), and for the cosmetic industry it was $ 231 billion (in 2005). These industries have important formulations based on marine extracts and therefore the bioprospecting values of marine ecosystems could be significant (Vierros *et al.*, 2007). The Convention on Bio-Diversity and the Bonn guidelines provide guidelines for international policy on access and benefit sharing arrangements (Naber *et al.* 2008).

7. Proposed methodology

7.1 Strength and weakness of methods

Each valuation method has strengths and weaknesses. As we have said earlier, due to the committed nature of behavioural response, revealed preference techniques are considered more robust and reliable than stated preference since these rely on expected behavior from hypothesised scenarios. However, revealed preference methods are unavailable for Non-Use valuation where we necessarily have to rely on Stated preference methods. So, if one were attempting a TEV of an ecosystem service, several techniques would need to be combined to arrive at reasonable values.

Some valuation techniques, depending on the circumstances could either yield an over-estimate or under-estimate of the value of the service. This problem is typical when using Replacement Cost (RC) methods. It is possible that an ecosystem may yield less value to society than the cost that society would have to incur if it had to be restored or replaced. There could be a situation where the cost of service provided by the ecosystem in terms of avoided damages is much lower than if the same service was provided for by alternate means.

There are some well-known biases with stated preference techniques (Cesar, 2000):

Hypothetical bias: The respondents know that the process is only dealing with a hypothetical situation they may not reveal true preferences.

Strategic bias: If people anticipate that their responses could influence forthcoming policy, they will answer strategically to shape policy – they may lower their bid if they feel that their statement may get converted into a tax or fee level.

Information bias: This is a critical error that may creep in due to design of the survey. The manner in which the hypothetical situation is described can influence bid responses. Design bias refers to the manner in which the queries are structured. Instrument bias occurs when the interviewee has a bias towards the payment vehicle. Starting-point bias is a well-known problem which refers to an outcome being disturbed because of the starting bid level.

8. Challenges

In the three ecosystem services that this scoping report engages with (namely, forests, wetlands and marine & coastal), the valuation literature in marine and coastal ecosystem services would be significantly thinner than the other two. The reason for this is the comparative lack of relevant natural science, social and economic data. This is true not only for India but also globally.

This report does not attempt to generate or aggregate the value for marine and coastal ecosystems as it is premature on many counts. The number of marine and coastal ecosystem services studies in India is limited. One could use the benefit transfer method to extrapolate values from other parts of the world but these need to be done with care as it could lead to inaccuracies (see Beaumont *et al.* 2006). Some of the values that have been generated for India need to be peer-verified for commonality of methodology. Scaling up from micro-studies to macro-region poses its own limitations. They do not account for regional variation (unless specifically incorporated). Further marine resources are mobile and move across several administrative jurisdiction in international borders and therefore present accounting problems.

Valuation of natural resources is expected to help better management of sustainable use and social allocation. Under-valuation can cause excessive extraction whereas over-valuation would result in under-utilisation. Given the state of knowledge about the scientific processes as well as methodological limitations, valuing restricts our ability to do this satisfactorily as many of the non-market valuation techniques are not proven. Having said that one must acknowledge that in the absence of any better estimates we have to work with what is currently available while constantly trying to improve upon them. Within the domain of valuation techniques, revealed preference methods are considered more reliable and robust and nearest to market valuation. Stated preference methods remain controversial despite the large body of literature that has now been accumulated. Improvement in contingent valuation techniques suggest that the difference in WTP values obtained from both these methods for quasi public goods can sometimes converge (Carson *et al.*, 1996).

Apart from the estimation of costs and benefits, the inter-temporal nature of the service flows causes additional problems. Simply stated, over-extraction of resource today may make the current generation well off but may reduce the future generation's well being. Therefore there is an ethical need for balancing off the need of the current generation against that of the future.

The benefits accrued from coastal and marine ecosystems are best discerned if they are compared with baseline conditions for the area under investigation. The initial and important step in valuation exercise is to consider that ecosystem service provision and benefits is a spatially explicit process. Hence there is a requirement to set the ecosystem under investigation in its spatial, socio-economic, political and cultural contexts (Turner *et al.* 2008). For valuation, it is "marginal" values that are required rather than aggregated values. As "marginal" values are surrounded by uncertainties of threshold effects, judging "marginal" effect is not straightforward.

A likely complication of collecting "marginal" values would be due to non-linearity between critical habitat variables and changes in ecosystem services. For instance, fringe mangroves may cause small losses, and not economic benefits of storm buffering. Data on such nonlinear functions of marginal losses are hard to collect.

Another challenge is to identify sources of double counting. Nutrient recycling, for example, will support a series of outcomes such as clean water, better support to life systems, higher productivity, etc. It should be kept in mind that economic values relate to end products, and not to nutrient recycling per se. It is important that the full range of complementary and competitive services should be distinguished before initiating valuation.

It may be possible to transfer data from other related studies as a guide to appropriate values. The procedure has problems and a strict protocol is required (Wilson and Hoehn 2006). Moreover, the benefits valuation methods and cost-based valuation cannot be aggregated in a simplistic way.

Given the urgent need for understanding the value of ecosystems and the wide differences in the available estimates, this is an area that will continue to engage researchers. Economic valuation will remain a challenging enterprise as it will have to negotiate with ecological non-linearity, uncertainties, existence of ecological thresholds, and conceptualization of resilience in the social context. Even if well executed micro-studies are available, there would still remain the issue of scaling up values of ecosystem services.

References

Anoop, P. and S. Suryaprakash. 2008. Estimating the option value of Ashtamudi Estuary in South India: a contingent valuation approach" presented at the 12th Congress of the European Association of Agricultural Economists, August 26, Ghent, Belgium. http:// ageconsearch.umn.edu/bitstream/43607/2/066.pdf.

Anoop, P., S. Suryaprakash, K.B. Umesh and T.S. Amjath Babu. 2008. Economic valuation of use benefits of Ashtamudi Estuary in South India. In: Proceedings of the Taal 2007: The 12th World Lake Conference, ed. M. Sengupta and R. Dalwani, 1822–1826. http:// moef.nic.in/ modules/recent-initiatives/nlcp/Indian%20Case%20Studies/Q-7.pdf.

Armstrong, C.W., N. Folely, R.Tinch and Sybille van den Hove. 2010. Ecosystem goods and services of the deep sea. http://www.pik-potsdam.de/news/public-events/archiv/alter-net/former-ss/2010/13.09.2010/van_den_hove/d6-2-final.pdf.

Arrow, K., Dasgupta, P., Goulder, L., Daily, G., Ehrlich, P., Heal, G., Levin, S., Mäler, K.-G., Schneider, S., Starrett, D., Walker, B., 2004. Journal of Economic Perspectives 18, 147–172.

Arrow, K. and R. Solow. 1993. United States. Report of the NOAA Panel on Contingent Valuation. National Oceanic and Atmospheric Administration.

Barbier, E.B. and I. Strand. 1998. Valuing mangrove-fishery linkages – a case study of Campeche, Mexico. Environmental and Resource Economics 12 (2): 151–166.

Beaumont, N., M. Townsend, S. Mangi and M. C. Austen. 2006. Marine Biodiversity An Economic Valuation: Building the Evidence Base for the Marine Bill. Department for Environment, Food and Rural Affairs (Defra), Plymouth. www.defra.gov.uk.

Bhat, M. G. and R. Bhatta. 2006. Mechanization and technical interactions in multi-species Indian fisheries: implications for economic and biological sustainability. Marine Policy 30 (3): 237–248.

Bockstael, N. E., A. M. Freeman, R. J. Kopp, P. R. Portney and V. K. Smith. 2000. On measuring economic values for nature. Environmental Science & Technology 34 (8): 1384–1389.

Brander, L. M., R. J. G. M. Florax and J.E. Vermaat. 2006. The empirics of wetland valuation: A comprehensive summary and a meta-analysis of the literature. Environmental & Resource Economics 33 (2): 223–250.

Carson, R.T., N.E. Flores, K.M. Martin and J.L. Wright. 1996. Contingent valuation and revealed preference methodologies: comparing the estimates for quasi-public goods. Land Economics 72 (1): 80–99.

Carson, R.T., R.C. Mitchell, M. Hanemann, R.J. Kopp, S. Presser and P. A. Ruud. 2003. Contingent valuation and lost passive use: damages from the Exxon Valdez oil spill. Environmental and Resource Economics 25 (3): 257–286.

Cesar, H.S.J. 2000. Coral Reefs: Their Functions, Threats and Economic Value. In Collected essays on the economics of coral reefs, ed. H. S. J Cesar, 14–39. Kalmar, Sweden: CORDIO: Sida.

Chopra, K., P. Kumar and P. Kapuria. 2010. Shrimp exports, environment and human well-being in the Sundarbans, West Bengal. In: Vulnerable Places, Vulnerable People, Trade Liberalization, Rural Poverty and the Environment, ed. J. A. Cook, O. Cylke, D.F. Larson, J.D. Nash and P. Stedman-Edwards, 63–77. Cheltenham, UK; Northampton, MA: Edward Elgar. http://site.ebrary.com/id/10391982.

Cisneros-Montemayor, M. M. Andrés and U. R. Sumaila. 2010. A global estimate of benefits from ecosystem-based marine recreation: potential impacts and implications for management. Journal of Bioeconomics 12 (3): 245–268.

Clough, B.F. 1994. Climate impacts on mangrove ecosystems. Conservation of mangrove forest genetic resources. M. S. Swaminathan Research Foundation, Chennai, India: 39: 487 pp.

CMFRI, 2011. Annual Report, 2010-11. Central Marine Fisheries Research Institute, Cochin, 163 pp.

CMFRI, 2012. Marine Fisheries Census, India, 2010. Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture and Central Marine Fisheries Research Institute, Cochin, Part, 1, 98 pp.

Conservation International. 2008. Economic Values of Coral Reefs, Mangroves, and Seagrasses: A Global Compilation. Arlington, VA: Center for Applied Biodiversity Science, Conservation International.

Costanza, R., R. d' Arge, R. de Groot, Stephen C. Farber, M. Grasso, B. Hannon and S. Naeem. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253–260.

DAHDF. 2000. Report of the Working Group for Revalidating the Potential of Fishery Resources in the Indian EEZ. Dept of Animal Husbandry & Dairying, Ministry of Agriculture, Govt. of India, New Delhi, 42 pp.

Das, S. 2009. Can mangroves minimize property loss during big storms? An analysis of house damage due to the super cyclone in Orissa. South Asian Network for Development and Environmental Economics, Kathmandu.

Das, S. and J. R. Vincent. 2009. Mangroves protected villages and reduced death toll during Indian super cyclone. Proceedings of the National Academy of Sciences 106 (18): 7357–7360.

Dasgupta, P. 2008. Discounting Climate Change. Journal of Risk and Uncertainty 37 (2-3): 141–169.

Dasgupta, P., 2009. The Welfare Economic Theory of Green National Accounts. Environmental and Resource Economics 42, 3–38.

Dasgupta, P., Maler, K.G., 2000. Net national product, wealth, and social well-being. Environment and Development Economics 5, 69–93.

Dixit, A. M., L. Kumar, P. Kumar and K. Pathak. 2012. Valuing the services of coral reef systems for sustainable coastal management: A case study of the Gulf of Kachchh, India. In: Valuation of regulating services of ecosystems: methodology and applications, ed. P. Kumar and M. D Wood, London: Routledge, 175–198.

Dixit, A. M., L. Kumar, P. Kumar, K. Pathak and M.I. Patel. 2010. Economic Value of Coral Reef Systems in Gulf of Kachchh. Final Report. World Bank aided Integrated Coastal Zone Management (ICZM) Project. Gandhinagar: Gujarat Ecology Commission.

DOD & SAC. 1997. Coral Reef Maps of India. Department of Ocean Development and Space Application Centre, Ahmedabad, India.

Ellison, J. C. and D. R. Stoddard. 1991. Mangrove ecosystem collapse during predicted sea level rise. Holocene analogues and implication. Journal of Coastal Research, 7: 151-155.

FAO. 2010. World Review of Fisheries and Aquaculture. Part 1. www.fao.org/docrep/013/pdf., 88 pp.

Farber, S. C. and R. Costanza. 1987. The economic value of wetlands systems. Journal of Environmental Management 24: 41–51.

Farber, S. C., R. Costanza and M. A. Wilson. 2002. Economic and ecological concepts for valuing ecosystem services. Ecological Economics 41 (3): 375–392.

Farber, S.C. and B. Griner. 2000. Using conjoint analysis to value ecosystem change. Environmental Science & Technology 34 (8): 1407–1412.

Field, C. 1993. Impacts of expected climate change on mangroves. Hydrobiologia 295: 75–81.

Freeman, A. M. 2003. The measurement of environmental and resource values: theory and methods. Resources for the Future, Washington, DC.

GEC. 2010. Economic valuation of coral reef systems in Gulf of Kachchh. Gujarat Ecological Commission, Ahmedabad, India.

Georgescu-Roegen, N. 1971. The entropy law and the economic process. Cambridge, Mass., Harvard University Press.

Gilman, E., J. Ellison and R. Coleman, 2007. Assessment of mangrove response to projected relative sea-level rise and recent historical reconstruction of shoreline position. Environmental Monitoring and Assessment 124: 112–134.

Gowdy, J. and J. Erickson. 2005. Ecological economics at a crossroads. Ecological Economics 53 (1): 17–20.

Guha, I. and S. Ghosh. 2007. Does tourism contribute to local livelihoods?: a case study of tourism, poverty, and conservation in the Indian Sundarbans. South Asian Network for Development and Environmental Economics, Kathmandu. http://www.sandeeonline.org / publicationdetails_disp.php?pcid=1&pid=750.

Guha, I. and S. Ghosh. 2009. A glimpse of the tiger: how much are Indians willing to pay for it? South Asian Network for Development and Environmental Economics, Kathmandu.

H M Treasury. 2011. The Green Book: Appraisal and Evaluation in Central Government, London. http://www.hm-treasury.gov.uk/d/green_book_complete.pdf.

Heal, G., 2004. Economics of Biodiversity: An Introduction. Resource and Energy Economics 26, 105–114.

Hirway, I. and S. Goswami. 2007. Valuation of coastal resources: the case of mangroves in Gujarat. Academic Foundation, New Delhi.

Hussain, S. A. and R. Badola. 2010. Valuing mangrove benefits: contribution of mangrove forests to local livelihoods in Bhitarkanika conservation area, east coast of India. Wetlands Ecology and Management 18 (3): 321–331.

ICAR. 2011. Handbook of Fisheries and Aquaculture. Indian Council of Agricultural Research, New Delhi, 1116 pp.

IOC. 2011. A Blueprint for Ocean and Coastal Sustainability. IOC/UNESCO/IMO/FAO/ UNDP, Paris, 45 pp.

IPCC. 2007. Climate Change: synthesis report. In: Contribution of Working Groups I, II and III, to the Fourth Assessment Report, eds, R.K. Pachauri and A. Reisinger, IPCC, Geneva, 104 pp.

Jeyabaskaran, R. 2009. New records of corals from Lakshadweep Islands. Records of Zoological Survey of India 109: 53-64.

Kathiresan, K. 2010. Importance of mangrove forests of India. Journal of Coastal Environment 1: 11-26.

Kelleher, G., C. Bleakley and S. Wells, editors. 1995. A Global Representative System of Marine Protected Areas. The World Bank, Washington, D.C.

Krutilla, J. V and A. C Fisher. 1975. The economics of natural environments: studies in the valuation of commodity and amenity resources. Washington, D.C.; Baltimore, Md.: Resources for the Future: Distributed worldwide by the Johns Hopkins University Press.

Kumar, P. ed. 2010. The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. London: Earthscan.

MARES, 2009. Conserving ocean ecosystems and safeguarding coastal communities. Marine Ecosystem Services Program, Forest Trends Publication, 8 pp.

Martínez, M., R. A Feagin, K. M. Yeager, J. Day, R. Costanza, J.A Harris, R. J. Hobbs, *et al.* 2012. Artificial modifications of the coast in response to the deepwater horizon oil spill: Quick solutions or long-term liabilities? Frontiers in Ecology and the Environment 10 (1): 44–49.

McLeod, E. and R. V. Salm. 2006. Managing mangroves for resilience to climate change. IUCN, Gland, Switzerland, 64 pp.

MoEF, 2005. Report of the Committee to review the Coastal Regulation Notification 1991. Ministry of Environemnt and Forests, New Delhi, 122 pp.

MoEF, 2009. India's Fourth National Report to the Convention on Biological Diversity. Ministry of Environment and Forests, Government of India, 156 pp.

Moriarty, D.J.W. and P.I.Boon, 1989. Interactions of seagrass with sediment and water. In: Biology of Seagrasses, eds. A.W.D. Larkum and S.A.Sheppard. Elsevier, Amsterdam, 500–535.

Mukhopadhyay, P. and G. K. Kadekodi. 2011. Missing the woods for the ore: Goa's development myopia. Economic and Political Weekly XLVI (46) (November 12).

Naber, H. G. Lange and M. Hatziolos. 2008. Valuation of Marine Ecosystem Services: A Gap Analysis. Washington, D.C: World Bank. http://www.cbd.int/marine/voluntary-reports/vr-mc-wb-en.pdf.

Narayanakumar, R., R. Sathiadhas and N. Aswathy, 2009. Economic performance of marine fishing methods in India. Marine Fisheries Information Service, Technology & Extension Series 200: 2-15.

Nature. 1998. Audacious bid to value the planet whips up a storm. Nature 395 (6701): 430.

NRC. 2004. Valuing ecosystem services: Toward better environmental decision-making. Washington, D.C: National Academies Press.

NRC. 2006. Dynamic changes in marine ecosystems fishing, food webs and future options. Washington, D.C.: National Research Council (U.S.). Committee on Ecosystem Effects of Fishing: Phase II--Assessments of the Extent of Change and the Implications for Policy, National Academies Press. http://site.ebrary.com/id/10132072.

Nunes, P.A.L.D., H. Ding and A. Markandya. 2009. The economic valuation of marine ecosystems. In Economic Valuation of Natural Coastal and Marine Ecosystems, ed. F. Briand, Monaco: CIESM Workshop Monograph 37: 23–34. http://www.feem.it/userfiles/ attach/Publication/NDL2009/NDL2009-068.pdf.

Patterson E.J.K., G. Mathews, J. Patterson, D.Wilhelmsson, J.Tamelander and O. Linden. 2007. Coral reefs of the Gulf of Mannar, southeastern India - distribution, diversity and status. SDMRI Special Research Publication.

Patterson, M. and A. Cole. 1999. Assessing the Value of New Zealand' Biodiversity. Occasional Paper. Palmerston North: School of Resource and Environmental Planning, Massey University.

Pearce, D. 2002. An intellectual history of environmental economics. Annual Review of Energy and the Environment 27 (1): 57–81.

Pearce, D. W and R. K. Turner. 1990. Economics of natural resources and the environment. Baltimore: Johns Hopkins University Press.

Pimentel, D., C. Wilson, C. McCullum, R. Huang, P. Dwen, J. Flack, Q. Tran, T. Saltman and B. Cliff. 1997. Economic and environmental benefits of biodiversity. Bioscience 47 (11): 747–757.

Planning Commission, 2011. Report of the Working Group on Ecosystem Resilience, Biodiversity and Sustainable Livelihoods for the XII Five Year Plan. Environment and Forest Division, Steering Committee, Government of India, 147 pp.

Rajagopalan, R. 2008. Marine Protected Areas in India. Samudra Monograph, International Collective in Support of Fishworkers, 87 pp.

Ramsey, F.P. 1928. A mathematical theory of saving. The Economic Journal 38 (152): 543–559.

Rao, P.V.S. and V.A. Mantri. 2006. Indian seaweed resources and sustainable utilization: scenario at the dawn of a new century. Current Science 91: 164-174.

Robbins, L. L., 1998. Major coastal and tidal ecosystems. In: Earth System: History and Natural Variability. Encyclopaedia of Life Supporting Systems 4: 27 pp.

SAC. 2010. Coral Reef Atlas of the World. Vol. I. Central Indian Ocean. Space Application centre (ISRO), Government of India.

Sathiadhas, R., R. Narayanakumar and N. Aswathy. 2011. Efficiency of domestic marine fish marketing in India – a macro analysis. Indian Journal of Fisheries 58: 125-134.

Sathyapalan, J. and S. Iyengar. 2007. Economic valuation of ecosystem changes: Salinity ingress and ground water depletion in coastal Gujarat. In Ecology and human well-being, eds. P. Kumar and B S. Reddy. New Delhi; Thousand Oaks, Calif.: Sage Publications.

Short, F., T. Carruthers, W. Dennison and M. Waycott. 2007. Global seagrass distribution and diversity: a bioregional model. Journal of experimental Marine Biology and Ecology 350: 3-20.

Singh, H S. 2002. Marine Protected Areas in India: Status of Coastal Wetlands and Their Conservation. Gujarat Ecological Education and Research Foundation (GEER), Ahmedabad.

Sridhar, R., T. Thangaradjou, L. Kannan and S. Astalakshmi. 2010. Assessment of coastal bio-resources of the Palk Bay, India using IRS-LISS-III data. Indian Journal of Remote Sensing 38: 565-575.

Srinath, M., Somy Kuriakose, K.G.Mini, M.R.Beena and Sindhu K. Augustine. 2004. Trends in landings. In: Status of Exploited Marine Fishery Resources of India, eds. M. Mohan Joseph and A. A. Jayaprakash, Central Marine Fisheries Research Institute, Cochin, 254-285.

Sumaila, R. (2010) A bottom-up re-estimation of global fisheries subsidies. In: Journal of Bioeconomics 12: 201- 225.

Sumaila, R. and D. Pauly. 2006. Catching more bait: A bottom-up re-estimation of global fisheries subsidies. Fisheries Centre, University of British Columbia, Canada.

TEEB. 2010. The economics of ecosystem and biodiversity: mainstreaming the economics of nature. A synthesis of the approach, conclusions and recommendation of TEEB, UNEP.

TEEB. 2012. Why Value Oceans? http://www.teebweb.org/Portals/25/Documents/TEEB %20for%20Oceans%20Discussion%20Paper.pdf.

Toman, M. 1998. Why not to calculate the value of the world's ecosystem services and natural capital. Ecological Economics 25 (1): 57–60.

Turner, R.K., T. Luisetti and D. Hadley. 2008. Valuing the coastal and marine ecosystem services. In Economic Valuation of Coastal and Marine Ecosystems, CIESM Workshop Monograph 37 (F. Briand, ed.), 65-71.

Turner, R. K., D. W. Pearce and I. Bateman. 1993. Environmental Economics: An Elementary

Introduction. Baltimore: The Johns Hopkins University Press.

UNDP. 2009. Biodiversity and ecosystems: Why these are important for sustained growth and equity in Latin America and the Carribean. Peru case study. United Nations Development Programme Report, 60 pp.

UNEP. 2006. Marine and coastal ecosystems and human well-being: A synthesis report based on the findings of the Millennium Ecosystem Assessment. United Nations Environment Programme, 76 pp.

UNEP. 2011a. Taking steps toward marine and coastal ecosystem-based management – an introductory guide (by T. Agardy, J. Davis, K. Sherwood and O. Vestergaard). UNEP Regional Seas Reports and Studies, 189: 68 pp.

UNEP. 2011b. Towards a Green Economy: pathways to sustainable development and poverty eradication (a synthesis for policy makers), United Nations Environment Programme, 123 pp.

UNEP-WCMC. 2011. Marine and Coastal Ecosystem Services: Valuation Methods and Their Application. UNEP-WCMC. www.unep-wcmc.org.

Venkataraman, K. and M. Wafar. 2005. Coastal and marine biodiversity of India. Indian Journal of Marine Sciences 34, 57-75.

Vierros, M., G. Hamon, D. Leary, S. Arico and C. Monagle. 2007. An Update on Marine Genetic Resources: Scientific Research, Commercial Uses and a Database on Marine Bioprospecting. New York: United Nations Informal Consultative Process on Oceans and the Law of the Sea Eight Meeting. http://www.ias.unu.edu/ resource_centre/Marine %20Genetic%20Resources%20 UNU-IAS%20Report.pdf.

Vivekanandan, E. 2011. Climate Change and Marine Fisheries. Central Marine Fisheries Research Institute, Special Publication 103, 97 pp.

Vivekanandan, E., M. Hussain Ali, B. Jasper and M. Rajagopalan. 2009. Vulnerability of corals to warming of the Indian seas: a projection for the 21st century. Current Science 97: 1654-1658.

Vivekanandan, E., Srinath, M. and Somy Kuriakose. 2005. Fishing the food web along the Indian coast. Fisheries Research, 72, 241-252.

प्रकृतिः रक्षति रक्षिता

Nature Protects if She is Protected

XI Conference of Parties

CONVENTION ON BIOLOGICAL DIVERSITY

HYDERABAD INDIA 2012