Food and Agriculture Organization of the United Nations

Valuing forest ecosystem services

A training manual for planners and project developers

FORESTRY WORKING PAPER

11

Valuing forest ecosystem services

A training manual
for planners and project developers

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Preface

A changing climate, a growing population, increasing demand for food and energy, expanding urban areas and many other factors pose severe threats to natural resources and biodiversity worldwide. The degradation of ecosystems can result in the potentially irreversible loss of ecosystem functions and services, with the ultimate effect of reducing human well-being. One of the biggest challenges facing humanity, therefore, is to manage natural resources in such a way that trade-offs between the increasing needs of the global population and the maintenance of ecosystem health are avoided or minimized.

Starting with the publication of the Millennium Ecosystem Assessment in 2005, ecosystem services have become increasingly prominent on the international policy and scientific agenda, receiving attention from scientists in various fields of research and among policymakers. The assessment of ecosystem services, including their economic valuation, is needed to better understand their importance and to inform decision making.

Although there is universal consensus that ecosystems and natural resources are important, determining their value to society is still subject to considerable debate. Scientific literature on the topic has grown, but technical information and training materials are still uncommon. The aim of this manual is to help fill the gap. The manual is intended as a training tool for officers and field practitioners working in environmental and forest agencies and other relevant areas of government. It focuses on forests and other tree-based ecosystems in Bangladesh but the concepts, methods and approaches described herein can be applied to a broad range of situations.

The target audience of the manual comprises those people who must consider the environmental costs and benefits of development projects but who don’t necessarily have a strong background in environmental economics. The aim is to build a robust knowledge of ecosystem services and their economic valuation through a step-wise approach. The manual explains the underlying concepts, provides definitions, sets out the principles of financial mathematics and economic valuation, and provides examples and exercises. Users will obtain a solid understanding of how to approach and deal with the valuation of ecosystem services and how to interpret valuation results and thereby inform development project design and decision making.

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Abbreviations and acronyms

BAU	business as usual
B/C	benefit/cost ratio
BDT	Bangladeshi taka
BLC	boat licence certificate
CBA	cost–benefit analysis
CICES	Common International Classification of Ecosystem Services
ES	ecosystem service
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
IRR	internal rate of return
MEA	Millennium Ecosystem Assessment
NPV	net present value
PES	payments for ecosystem services
REDD+	reducing emissions from deforestation and forest degradation, plus the role of conservation, sustainable management of forests, and the enhancement of forest carbon stocks
SEEA	System of Environmental-Economic Accounting
TEEB	The Economics of Ecosystems and Biodiversity
TEV	total economic value
USD	United States dollar(s)
WTA	willingness to accept
WTP	willingness to pay

MEASUREMENT UNITS

ha	hectare (equivalent to 10 000 m^2)
kg	kilogram (equivalent to 1 000 grams)
km	kilometre (equivalent to 1 000 m)
m	metre

Executive summary

The degradation of ecosystems, including forests, and the associated loss of biodiversity, particularly due to human-induced threats and climate change, has gained increased attention from scientists and policymakers. The Millennium Ecosystem Assessment presented a new conceptual framework that puts ecosystem services at the centre and links human well-being to the impacts on ecosystems of changes in natural resources. The Economics of Ecosystems and Biodiversity initiative drew further attention to the economic benefits of conserving ecosystems and biodiversity, supporting the idea that economic instruments – if appropriately applied, developed and interpreted – can inform policy- and decision-making processes. Only a few ecosystem services, however, have explicit market value and are traded in open markets: many – especially those categorized as having "passive-use" value – remain invisible and are rarely accounted for in traditional economic systems. The failure to appropriately consider the full economic value of ecosystem services in decision making enables the continued degradation and loss of ecosystems and biodiversity. Most ecosystem services are considered public goods and tend to be overexploited by society.

Many methods have been applied to the economic valuation of ecosystem services. The use of these methods, as well as the interpretation of their results, requires familiarity with the ecological, political, normative and socio-economic context and the science of economics. Recognizing, demonstrating and capturing the value of ecosystem services can play an important role in setting policy directions for ecosystem management and conservation and thus in increasing the provision of ecosystem services and their contributions to human well-being.

The aim of this manual is to enhance understanding of ecosystem services and their valuation. The specific target group comprises governmental officers in planning units and field-level officers and practitioners in key government departments in Bangladesh responsible for project development, including the Ministry of Environment and Forests and its agencies. Most of the examples and case studies presented herein, therefore, are tailored to the Bangladesh context, but the general concepts, approaches and methods can be applied to a broad spectrum of situations. This manual focuses on valuing forest-related ecosystem services, including those provided by trees outside forests. It is expected to improve valuation efforts and help ensure the better use of such values in policymaking and decision making.

Among other things, the manual explores the basics of financial mathematics (e.g. the time value of money; discounting; cost–benefit analysis; and profitability and risk indicators); the main methods of economic valuation; examples of the valuation of selected ecosystem services; and inputs for considering values in decision making.

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Module 1 | Introduction

KEY MESSAGES

- In the last few decades, growing demand for food, fresh water, timber, fibre and fuel, have changed and degraded ecosystems more rapidly and extensively than in any comparable previous period.
- Natural resources and environmental degradation can negatively affect the capacity of ecosystems to contribute to human well-being.
- Valuing natural resources and the services they deliver is crucial for informed decision making and for driving sustainable investment choices.

This module provides the rationale for the manual and the background information needed for its use. It provides insights into the important roles of ecosystem services (ESs) and why their valuation matters. It describes the manual's aims, focus, target audience, structure, content and limitations (in terms of scope and application). The module also introduces scenarios specific to the context of Bangladesh, which can be used as references, examples and exercises in considering the approaches, methods and concepts presented in the manual.

1.1 THE TRAINING MANUAL: AN OVERVIEW

Challenges and rationale for this module

Forests and trees play crucial roles in achieving the goals of the three Rio conventions – the United Nations Framework Convention on Climate Change, the Convention on Biological Diversity, and the United Nations Convention to Combat Desertification. The growing importance of ecosystem services in global policy development can be seen in the Paris Agreement on climate change, emerging REDD+ activities,[1] and a range of global and regional initiatives, commitments and programmes. These include the Global Goals of the United Nations Forum on Forests; the Convention on Biological Diversity's Aichi Biodiversity Targets; the Bonn Challenge; the New York Declaration on Forests; and the Sustainable Development Goals, particularly Goal 15, which refers to sustainable land and forest management. The need to ensure the sustainability and enhance the supply of goods and services from forests and other tree-based ecosystems is gaining increasing policy attention and work on the ground.

[1] REDD+ = reducing emissions from deforestation and forest degradation, plus the role of conservation, sustainable management of forests, and the enhancement of forest carbon stocks.

ESs are the "multiple benefits provided by ecosystems to humans" (MEA, 2005); they constitute both the "direct and indirect contributions of ecosystems to human well-being" (TEEB, 2010a). Valuing forest-based ESs – that is, those services delivered by forest ecosystems, including trees outside forests – and incorporating the values generated in policymaking and decision making has gained increasing attention in recent years, especially given threats to the sustainable provision of ESs.

Globally, ecosystems and biodiversity are being degraded and lost due to direct drivers – such as habitat disturbance, land-use change, overexploitation and the spread of alien species – and indirect drivers such as climate change, population growth, economic growth and increasing demand for food, materials, water and energy. The Millennium Ecosystem Assessment (MEA, 2005) showed that human activity is putting pressure on natural resources to the extent that the world's ecosystems are progressively losing – sometimes irreversibly – their capacity to contribute to human well-being and to sustain future generations. The effects of ecosystem degradation and the consequent decrease in their functioning and resilience impose costs that are being borne disproportionately by poor people, thus contributing to growing inequalities and disparities. Ecosystem degradation is sometimes the principal factor causing poverty and social conflict (Box 1).

BOX 1

Four main findings of the Millennium Ecosystem Assessment

1. Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period in human history, largely to meet growing demands for food, fresh water, timber, fibre and fuel. This has resulted in a substantial and largely irreversible loss of biodiversity.
2. The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development, but these gains have been achieved at growing costs in the form of the degradation of many ecosystem services, increased risks of nonlinear changes, and the exacerbation of poverty for some groups of people. These problems, if unaddressed, will substantially diminish the benefits that future generations obtain from ecosystems.
3. The degradation of ecosystem services could grow significantly worse in the first half of this century and is a barrier to achieving the Millennium Development Goals.2
4. The challenge of reversing the degradation of ecosystems while meeting increasing demands for their services can be met partially, but this requires significant changes in policies, institutions and practices that are not currently under way. Many options exist to conserve or enhance specific ecosystem services in ways that reduce negative trade-offs or that provide positive synergies with other ecosystem services.

Source: MEA (2005).

2 And also the Sustainable Development Goals.

Many of the direct and indirect drivers of ecosystem degradation and biodiversity loss are important in Bangladesh, posing serious threats to local ecosystems and challenges to the livelihoods, health and quality of life of people. Forest cover is low in Bangladesh (roughly 18 percent of the total land area), and the rate of deforestation has been relatively steady over time (about 0.2 percent per year) (FAO, 2015). Up to 90 percent of Bangladesh's forests have been lost or degraded due to various pressures, such as population growth, development, gaps in policy and legislation, and conflicting institutional mandates (Kibria *et al*., 2011; Rahman, De Groot and Snelder, 2008; Rasul, Thapa and Zoebisch, 2004). Bangladesh is one of the world's most densely populated countries, and more than 60 percent of people live in rural areas (World Bank, 2017a). About 19 million people depend directly – and tens of millions more[3] depend indirectly – on forests and other natural resources for their livelihoods (Barua, Boscolo and Animon, 2017). Bangladesh is recognized widely as one of the most vulnerable countries to climate change due to its physical, demographic and socio-economic features. Data on damage and losses caused by natural shocks and climate-related disasters such as cyclones and floods show that these mostly occur in areas that also have high concentrations of the poor, thus affecting them disproportionately (World Bank, 2010). At least 100 ministries and agencies of the Government of Bangladesh are implementing programmes to mitigate the effects of these challenges, but more and better investments are needed. Planning and development units in ministries and agencies play crucial roles because they are the entities that identify, formulate and appraise projects.

As reported in MEA (2005), serious limits exist in the expertise available for the economic valuation of ESs, to monitor changes in their provision, and to include ESs in analyses and policymaking related to ecosystem management and development projects. This constraint can be overcome through training in existing institutions. An area in which project formulation and appraisal needs to be improved is the valuation and accounting of ESs that could be affected (positively or negatively) by project activities. Methodologies and tools are available that enable practitioners to properly value ESs. The methodologies are not new, but they need to be applied appropriately in decision making.

Why valuing ecosystem services matters

Although all people depend on nature for their well-being (see section 2.3), the benefits of nature are often neglected in policies; moreover, losses in natural capital have direct economic consequences that are often underestimated. The benefits deriving from ESs and the costs of the degradation and loss of ecosystems and biodiversity are incurred on the ground but may be largely unnoticed at a larger scale (TEEB, 2009). What are the consequences of this, and why does the valuation of ESs matter?

Valuation can be defined as the process of attributing a certain economic or non-economic value to something. This manual focuses on the economic valuation of ESs – that is, valuation that measures, in monetary terms, people's preferences for the benefits

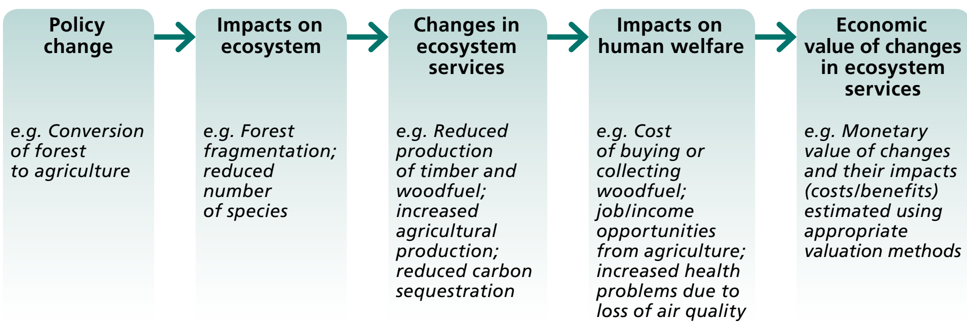
[3] According to the Forest Peoples Programme, about 114.5 million people, including 3 million indigenous people, are directly or indirectly dependent on wetlands and forests in Bangladesh (Chao, 2012).

they get from ESs (see section 2.3 for discussion of the concepts of value and valuation). A lack of, or inadequate, ES valuation can lead to the overexploitation of the resource stocks generating those services, such as the overharvesting of timber and the consequent degradation or loss of the forests supplying the timber. A lack of, or inadequate, ES valuation can also result in poorly informed decisions in the design of projects or investments or in choosing among land-use options. For example, a simplistic evaluation of the costs and benefits of converting a forest to, say, intensive agriculture that ignores the loss of ESs provided by the forest could result in net negative economic outcomes in the long term.

For each option (e.g. maintaining a forest or converting to another land use), the impacts on ecosystems should be evaluated, including the associated impacts in the provision of ESs (e.g. reduced woodfuel and timber production; increased production of agricultural crops; reduced carbon sequestration and air quality; reduced water quality; changes in microclimatic conditions, such as increased temperatures; and reduced forest recreation and landscape amenity). Such changes may affect human welfare – such as by increasing the need to buy or collect woodfuel elsewhere; increasing the number of job and income opportunities through agriculture; reducing human health due to worsening air quality and the costs associated with medical care; reducing water quality; and increasing the travel costs associated with forest recreation.

It is possible to estimate the economic value associated with changes in ESs (Figure 1). Such valuations can be used in assessing the impacts of land-use changes, implementing ecosystem management options (e.g. forest conservation through set-asides versus active forest management), and comparing options for providing services and the investments involved (e.g. coastal protection through mangrove forest conservation, compared with the building of new grey infrastructure like seawalls). Valuations can help in revealing the relative importance of different ESs, establishing priorities, informing decision makers, guiding budgeting and resource allocation (e.g. financing, subsidies and investments), and managing potential trade-offs and consequent conflicts among ES beneficiaries.

FIGURE 1
The sequence for valuing the costs and benefits of ecosystem services due to policy change



Source: Modified from TEEB (2009).

Decision makers need to understand the ESs generated by natural capital in zones under their responsibility; the extent to which ESs are (at risk of) being lost; which ESs might be enhanced; the economic costs of losing ESs; and who incurs these costs and where and when. Valuations can help in developing the necessary evidence base and should address spatial relationships among the sources and beneficiaries of ESs (TEEB, 2009).

Aims and focus of the manual

Why another manual? The volume of literature on ESs has grown rapidly in recent years, especially in light of initiatives such as the MEA,[4] the Common International Classification of Ecosystem Services (CICES),[5] The Economics of Ecosystems and Biodiversity (TEEB),[6] New Ways to Value and Market Forest Externalities,[7] and Mapping and Assessment of Ecosystems and their Services.[8] The capacity for valuing ESs has increased in some countries but needs strengthening in others. In Bangladesh, the Ministry of Environment and Forests is implementing the project "Strengthening the Environment, Forestry and Climate Change Capacities of the Ministry of Environment and Forests and its Agencies" (funded by the United States Agency for International Development) with the aim of increasing its capacity to deliver effective, coordinated, sustainable and country-driven investment programmes in environmental protection, sustainable forest management and climate-change adaptation and mitigation. The modules in this manual are designed, therefore, to increase the capacity of officers in the ministry to develop better projects that take into account the benefits and costs of improved resource management. The manual should help build awareness of the need to internalize the costs of environmental degradation in decision making and to evaluate the full costs and benefits of projects and other interventions.

The manual will help in valuing ESs and in making use of such valuations in policymaking and decision making, with special attention on forests and other tree-based ecosystems in Bangladesh.

Specifically, the manual aims to:

- make readers aware of the value of ecosystems and ESs and the importance of valuing them;
- explain common concepts, definitions, approaches and methods in the valuation of ESs;
- provide valuation examples and case studies;
- provide users with exercises in which they can put into practice the concepts and approaches outlined in the manual; and
- provide a practical framework for embedding ES valuation in decision-making processes.

4 www.millenniumassessment.org
5 http://cices.eu
6 www.teebweb.org
7 www.newforex.org
8 http://biodiversity.europa.eu/maes

The manual provides a theoretical background and detailed practical insights into the challenge of valuing the ESs performed by forests and other tree-based ecosystems. Where possible, case studies are tailored to the Bangladesh context, but the concepts, approaches and methods are applicable to a broad spectrum of situations.

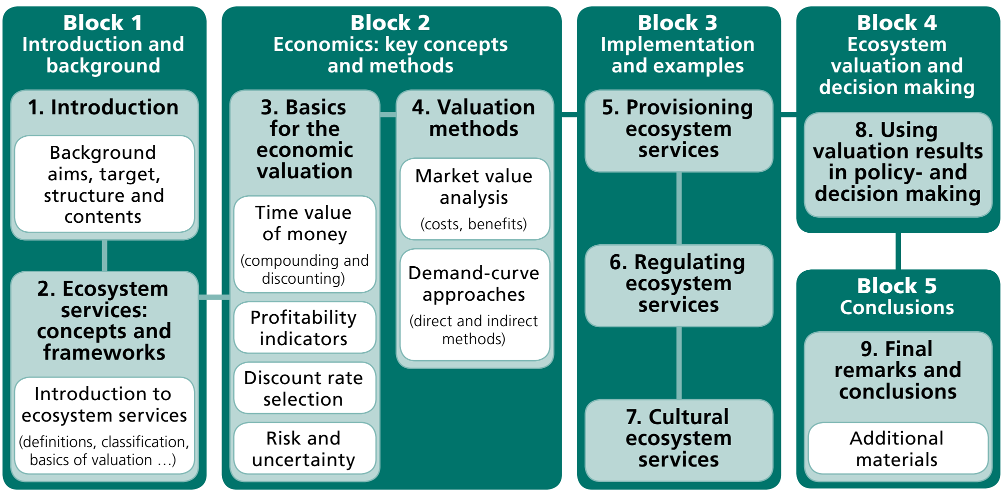
Intended audience and users

The manual is targeted at officers in government departments responsible for project development, including the Ministry of Environment and Forests and its agencies, planning units and field staff.

Outline and structure of the manual

The document consists of five main blocks and nine modules (Figure 2), as follows:

FIGURE 2
General outline and structure of the manual



1. *Introduction and background* (modules 1 and 2) – introduces the manual and the key concepts in the ES domain (e.g. definitions and classification systems).
2. *Economics: key concepts and methods* (modules 3 and 4) – gives basic information on key aspects such as financial and mathematic concepts, user-friendly software for performing financial and economic analyses, and valuation methods using market-value analysis and demand-curve approaches.
3. *Implementation and examples* (modules 5, 6 and 7) – provides concepts and definitions, methodological approaches and examples for various categories of ESs (provisioning, regulating and cultural).

4. *Ecosystem valuation and decision making* (module 8).
5. *Conclusions* (module 9) – final remarks, references and annexes.

Each module contains a box summarizing the module's key messages; a comprehensive exploration of the topic supported by figures, summary tables, examples and – where relevant – exercises; and reflection points to check readers' understanding of the module and to encourage the further development of concepts through practical exercises.

Limitations

The manual focuses on those ESs that are most relevant to Bangladesh (Barua, Boscolo and Animon, 2017). Consequently, not all ESs and valuation methods receive in-depth coverage.

1.2 FRAMING THE VALUATION OF ECOSYSTEM SERVICES AND DECISION MAKING: HYPOTHETICAL EXAMPLES IN BANGLADESH

In order to link the theoretical concepts and methodological approaches presented in the manual with close-to-reality examples, five hypothetical scenarios in the context of Bangladesh are presented below. The manual does not provide solutions to these scenarios but, rather, it sets out methodological processes and approaches that could be used in dealing with them. Some of these scenarios are referred to in later modules addressing ES valuation methods. Trainers and readers are encouraged to use the scenarios for a better understanding of the concepts delivered in the manual and use them by putting the knowledge gained into practice and developing additional exercises and discussions.

Scenario 1: cost–benefit analysis of a large coastal afforestation programme

The Government of Bangladesh is proposing a large coastal afforestation programme to protect the livelihoods of communities living in southern coastal areas and on offshore islands. The afforestation programme has clear cost implications. Detailed estimates exist of the cost of planting and maintaining various species on coastal lands. Estimating the benefits for local communities is an elusive exercise, however.

There is a risk that the proposed programme will not be funded unless a detailed cost–benefit analysis can be done that includes both financial and economic assessments of the costs and benefits. You have been asked to estimate the benefits of coastal forests in terms of the production of woodfuel, timber and fodder; reduced damage due to storm and tidal surges; higher productivity of fisheries; land stabilization; the control of salinity intrusion; and the provision of other key ESs that local communities may derive from these forests.

Scenario 2: national incentive scheme for tree planting

The Government of Bangladesh has set a target to increase the national forest cover to 15 percent by 2021. Recent analyses suggest that farmers, particularly in the northern part of the country, are, by their own initiative, planting trees on their land and that the magnitude of these activities could help meet the national target. Anecdotal evidence suggests that tree planting by farmers could be scaled up significantly if an incentive scheme was designed and implemented. As the officer in charge of planning, you have been asked to determine the type of incentive scheme, and its scale (in USD/ha), that would motivate farmers to increase their tree planting by 10 percent. The design of the incentive scheme should take into account the opportunity cost of allocating land to trees instead of other agricultural production and the benefits that farmers will derive from trees over multiple years.

Scenario 3: setting the entrance fee for a park

Tens of thousands of people visit the Bangabandhu Sheikh Mujib Safari Park in Gazipur district (close to Dhaka) each year. Table 1 shows the existing entrance fee structure.

TABLE 1. **Entrance fee structure for the Bangabandhu Sheikh Mujib Safari Park**

Nationality of visitor	Visitor type	Entrance fee (BDT)
A. Bangladeshi	Adult	60 per person
	Child (age 3–6 years)	25 per person
	Child (age less than 3 years)	No fee
	Primary or high school student (age less than 15 years)	15 per person
	Student group (10–50 individuals)	500 per group
	Student group (51–100 individuals)	750 per group
	Student group (more than 100 individuals)	1 000 per group
B. Foreigner	All visitor types	400 per person

Even though the total revenue earned from entrance fees amounts to tens of millions of Bangladeshi taka per year, maintaining the park and scaling up certain services has become a challenge. You have been asked to propose an increase in the entrance fees that would increase park revenues by at least 50 percent while causing a minimal reduction in visitation rates. How much could the entrance fee be increased for different visitor types without significantly affecting visitation? What sorts of services, if improved, could economically justify a higher entrance fee and possibly also increase visitation rates?

Scenario 4: assessing trade-offs between urban development and green-area conservation

One of the two city corporations in Dhaka is considering allocating an area that is currently a green area to the development of apartment buildings. The press is claiming that the conversion of the area to buildings will reduce the value of existing buildings because of increased pollution and congestion and reduced access to amenities such as recreation and scenic beauty, among other impacts. To inform the decision-making process, you have been asked to analyse the issue and to provide an assessment of the economic costs of a reduction in ESs due to a reduction in green area.

Scenario 5: analysing the environmental externalities of a power plant and their costs

The construction of a large power plant has been proposed in the proximity of the Sundarbans Forest Reserve, a World Heritage site. The power plant may affect nearby ecosystems by increasing air pollution and modifying water temperatures. Indirectly, the transport of fossil fuels may also modify the composition of floral species, with adverse impacts on faunal diversity in the reserve. The Bangladesh Forest Department has been asked to estimate the environmental costs of the plant and to recommend the conditions under which the project could proceed.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Module 2 Ecosystem services: concepts and frameworks

KEY MESSAGES

- The MEA defines ESs as the "multiple benefits provided by ecosystems to humans". ESs comprise all products and services that ecosystems deliver to humans and contribute to human well-being, either directly (e.g. by providing food, materials and water) or indirectly (e.g. by ensuring protection against hazards and mitigating climate change).
- Ecosystem services can be classified as *provisioning* (i.e. providing products and materials); *regulating* (i.e. regulating ecosystem processes and the environment); and *cultural* (i.e. the non-material benefits obtained from ecosystems, such as cultural and spiritual values). A fourth category (*supporting* services) includes all the underlying structures, processes and functions that characterize ecosystems.
- Although all people depend on nature for their well-being, nature's benefits are often neglected in policies, and the economic consequences of environmental degradation are often underestimated. In part, this is because only a few ESs have explicit value (i.e. are traded in markets): many benefits are "invisible" and rarely accounted for in traditional systems. The failure to consider the full economic value of ESs in decision making results in ongoing ecosystem degradation and, ultimately, in a reduction in human well-being.
- Valuation is the process of attributing a value to something. It aims to measure, in monetary terms, people's preferences for the benefits they obtain from (for example) ESs. Valuing ESs is part of informing political decision making: it can help in balancing the trade-offs in resource allocation when designing projects or investments and choosing among alternative land uses.
- The concept of value refers to the measurement of the extent to which people want or like something. There are two broad categories of economic value: *use* value and *passive-use* (sometimes also called *non-use*) value. The sum of these values provides the total economic value.

This module introduces ESs and their classification and links to human well-being. It also discusses basic concepts and types of economic values.

2.1 DEFINING ECOSYSTEM SERVICES

An ecosystem is a community of living (biotic) organisms – animals, plants and microorganisms – interacting with the physical environment (e.g. air, water and mineral soil) as an interdependent system (Odum, 1971). Ecosystems can be terrestrial or marine, inland or coastal, and rural or urban; they may be global in scale or very local, and they often overlap and interact. This manual focuses on forest ecosystems (and trees outside forests) in Bangladesh, where forests play key roles in providing income and supporting livelihoods, contributing at the same time to climate-change mitigation and other important ESs.

ESs are the "multiple benefits provided by ecosystems to humans" (MEA, 2005) and the "direct and indirect contributions of ecosystems to human well-being" (TEEB, 2010a). From an economic perspective, ESs have been described as the "contributions of the natural world which generate goods which people value" (Bateman *et al.*, 2011). Thus, ecosystems and their functions generate services that give rise to goods and services that people value because they derive benefits from them (Haines-Young and Potschin, 2011a). This implies that ESs include both "final" ESs, which make the greatest contributions to economic and social well-being (e.g. agricultural crops), and "intermediate" ESs (e.g. pollination) that support "final" ESs (Haines-Young and Potschin, 2011b).

ESs thus consist of all the goods and services provided by an ecosystem (e.g. a forest) that benefit people. Examples of ESs include the production of woodfuel; carbon sequestration; water regulation; and the provision of habitat for biodiversity (Figure 3). Some ESs are tangible and well known in daily life (e.g. the provision of food, fibre, other materials and fuel) and others are intangible and less known or easily perceived (e.g. climate regulation, water filtration, and protection against extreme events and hazards). Sometimes the link between ecosystems and the benefits they provide is direct, and sometimes it is subtler and less evident.

The study of interactions between people and the environment, with a focus on the effects of nature's services on human well-being, has a long history (Marsh, 1864).

FIGURE 3
Examples of ecosystem services delivered by forests

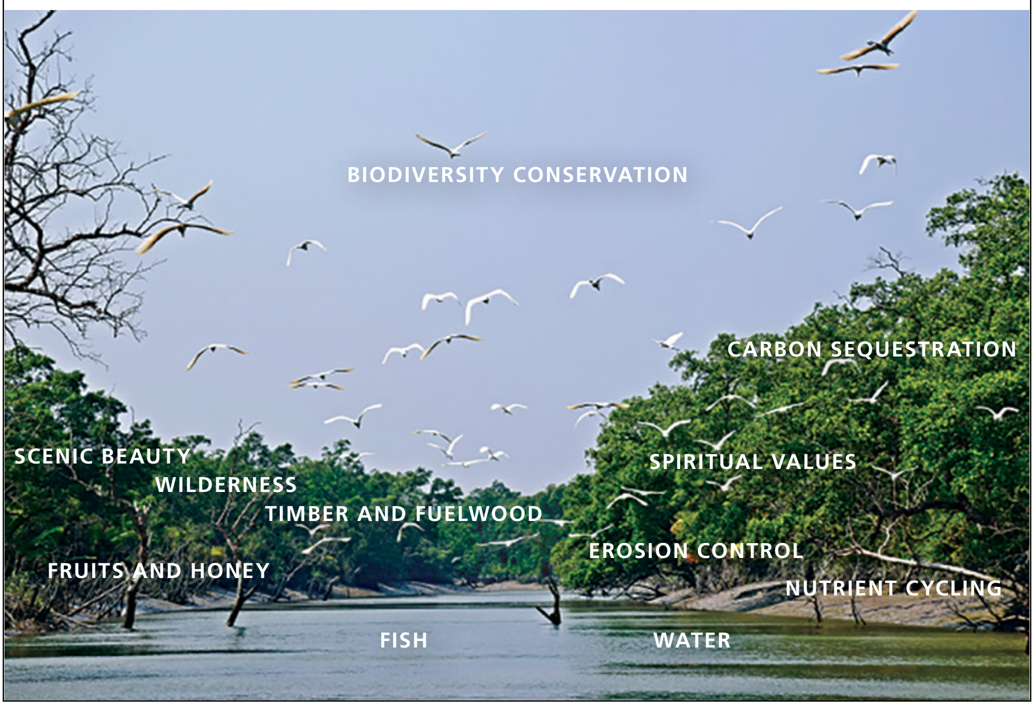


Photo ©Falgoonee Kumar Mondal

In the second half of the 1990s, however, ESs began to receive increased attention in the scientific community and greater visibility internationally (Gómez-Baggethun *et al*., 2010). ESs gained a place on the global policy agenda with the publication of the MEA, which provided a classification of ESs (see 2.3) and emphasized the dependency of human well-being on such ESs and ultimately on the functioning of ecosystems. Recent initiatives include TEEB, launched in 2007, and Wealth Accounting and the Valuation of Ecosystem Services Partnerships promoted by the World Bank from 2010. There is also greater focus on the economics of ESs, such as through natural capital accounting and the identification and implementation of policy and market tools to remunerate the provision of ESs. For example, the System of Environmental-Economic Accounting (SEEA), recently endorsed by the United Nations Statistical Commission,[9] encourages the measurement, recording and accounting of ESs through its "experimental ecosystem accounting". The aim of SEEA is to go beyond other approaches to ecosystem analysis and assessment by explicitly linking ecosystems to economic and other human activities. Such links are observable both in the services provided by ecosystems and in the impacts that economic and other human activities have on ecosystems and their future capacity (United Nations, 2017). SEEA-Agriculture, Forestry and Fisheries helps in organizing data to enable the description and analysis of relationships among economic activities in agriculture, forestry, fisheries and the environment (Box 2).[10]

BOX 2

The System of Environmental-Economic Accounting for Agriculture, Forestry and Fisheries

The System of Environmental-Economic Accounting for Agriculture, Forestry and Fisheries (SEEA-AFF) is a statistical framework that adapts and extends to these primary sectors the environmental-economic structure and principles of the SEEA Central Framework.

SEEA-AFF covers a broad range of data (both monetary and biophysical) in ten primary data domains, including "forestry products and related environmental assets". SEEA-AFF defines core national accounting tables to be used as a basis for the measurement and reporting of information on assets and flows related to natural resource use in the production, trade and consumption of agricultural, forestry and fisheries products. SEEA-AFF could be extended to incorporate the inputs and outputs of ecosystem services.[11]

Source: United Nations (2017); FAO (2017).

9 The SEEA Central Framework was adopted in 2012 by the United Nations Statistical Commission as an international statistical standard and published in 2014 by the United Nations, the European Commission, FAO, the International Monetary Fund, the Organisation for Economic Co-operation and Development and the World Bank (United Nations, 2017).

10 See https://unstats.un.org/unsd/statcom/47th-session/documents/BG-2016-8-SEEA-Agriculture-E.pdf

11 See www.fao.org/economic/ess/environment/methodology

The study of ESs can be approached from various perspectives and with differing aims. Nevertheless, two cross-cutting aspects normally provide the basis for most research initiatives: classification systems for ESs; and the fact that many ESs qualify – in economic terms – as public goods. Given their importance for the objectives of this manual, these two aspects are addressed further below.

How ecosystem services are classified

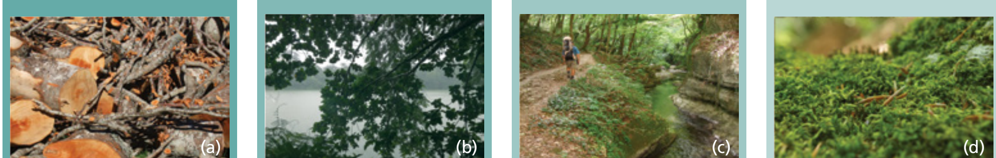
The classification of ESs has been debated widely in recent years (De Groot, Wilson and Boumans, 2002; Boyd and Banzhaf, 2006; Wallace, 2007; Fisher *et al.*, 2008; Costanza, 2008), and many classification schemes have been proposed. A globally recognized scheme was introduced in MEA (2005) and adopted in several studies and initiatives. MEA (2005) defined four ES categories (Figure 4):

1. **Provisioning** – products and materials obtained from ecosystems, such as food, fibres, building materials, fresh water, energy, biochemicals and genetic resources.
2. **Regulating** – benefits obtained from the regulation of ecosystem processes and the environment, such as climate regulation, disease regulation, water regulation, water purification, pollination, soil protection, carbon sequestration, and protection against natural hazards and extreme events.
3. **Cultural** – nonmaterial benefits obtained from ecosystems that enrich lives, such as spiritual and religious values, recreation and tourism, aesthetic value and landscape, inspirational value, education, research, sense of place, and cultural heritage.
4. **Supporting** – underpinning services that enable other services to function, such as soil formation, nutrient cycling and primary production.

FIGURE 4

The classification of ecosystem services according to the Millennium Ecosystem Assessment

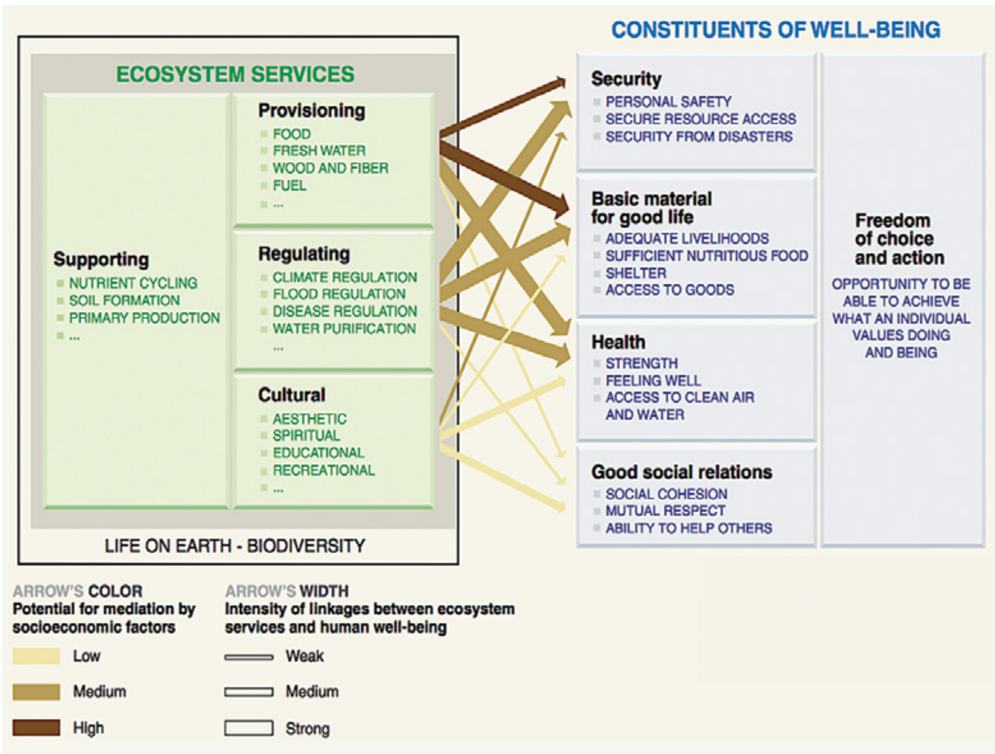
PROVISIONING SERVICES	REGULATING SERVICES	CULTURAL SERVICES	SUPPORTING SERVICES
Products obtained from ecosystems	*Benefits obtained from regulation of ecosystem processes*	*Nonmaterial benefits obtained from ecosystems that enrich lives*	*Underpinning services that enable other services to function*
• Food • Fresh water • Fuel wood • Fibre • Biochemicals • Genetic resources	• Climate regulation • Disease regulation • Water regulation • Water purification • Pollination	• Spiritual & religious • Recreation & ecotourism • Aesthetic • Inspirational • Educational • Sense of place • Cultural heritage	• Soil formation • Nutrient cycling • Primary production



Source: modified from MEA (2005). Photos: (a), (c) and (d): © Mauro Masiero; (b) © Sepul Kanti Barua.

The ES categories are linked to, and interact with, human well-being. As shown in Figure 5, well-being is assumed to have multiple constituents, including the following: *basic material for a good life*, such as secure and adequate livelihoods and access to sufficient food, shelter and clothing; *health*, including feeling well and having a healthy physical environment, such as clean air and access to clean water; *good social relations*, including social cohesion, mutual respect, and the ability to help others and provide for children; *security*, including secure access to natural and other resources, personal safety, and security from natural and human-made disasters; and *freedom of choice and action*, including the opportunity to achieve what an individual values doing and being. Freedom of choice and action is influenced by other constituents of well-being (as well as by other factors, notably education) and is also a precondition for achieving other components of well-being, particularly with respect to equity and fairness (MEA, 2005).

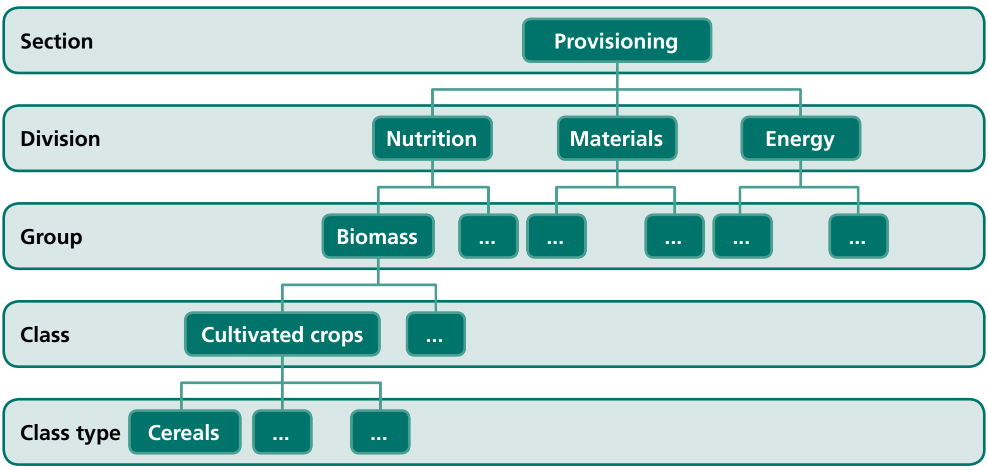
FIGURE 5
Linkages between categories of ecosystem services and components of human well-being



Source: MEA (2005).

Many initiatives have adopted the MEA's four-category classification of ESs, sometimes with slight adaptation and adjustments. Nevertheless, ongoing debate in the scientific and policy arenas has encouraged the further development of the classification. TEEB, for example, adopted the provisioning, regulating and cultural categories but introduced a "habitat services" category. CICES, launched in 2009, excludes the supporting services category because such services are considered part of the underlying structures, process and functions that characterize ecosystems. Supporting services are consumed or used indirectly and may simultaneously facilitate the output of many "final outputs"; therefore, they are considered to be best dealt with in environmental accounts in other ways.[12] CICES provides a hierarchical system with "sections" (i.e. provisioning, regulating and cultural) and, within each section, classifications ranging from very general ("division") to extremely detailed ("class" and "class type") (Figure 6). Each level in the hierarchy provides an increasingly detailed description of the ESs being considered. This nomenclature has evolved over time and reflects advice from the United Nations Statistical Division based on its best-practice guidelines. Unless otherwise indicated, this manual refers to the CICES nomenclature. Annex 1 provides additional information and a comparative summary of the main ES classification systems.

FIGURE 6
An example of the Common International Classification of Ecosystem Services hierarchical system



Source: Modified from CICES (2017a).

[12] https://cices.eu/cices-structure

2.2 CONCEPTUAL FOUNDATION FOR THE ECONOMIC VALUATION OF ECOSYSTEM SERVICES

Valuing ESs is a step in the political decision-making process towards ensuring human well-being (Daily *et al*., 2009). Valuation and economic analysis provide decision makers with information on how society might balance the trade-offs inherent in resource-allocation decisions (TEEB, 2010a; Markandya *et al*., 2007). Moreover, valuation is a prerequisite for creating market-based mechanisms, such as payments for ecosystem services (PES), to encourage the provision of ESs (Landell-Mills and Porras, 2002; Wunder, 2005).

Reasons for valuing ESs include the identification of missing markets; the internalization of externalities in planning and project formulation; the correction of market failures; the assessment of synergies and trade-offs among different land uses; the setting of market-based instruments for ESs and development of market opportunities; the management of uncertain future supply-and-demand scenarios for natural resources; the design of ecosystem conservation initiatives and programmes by both private and public actors; and natural resource accounting (Fisher *et al*., 2008; Turner, Pearce and Bateman, 1994; Costanza *et al*., 1997; Pascual and Muradian, 2010; Panayoutou, 1993). Module 8 provides details on how to include valuation in policy- and decision-making processes.

Economists have debated the meaning of "value" – what it is and how to measure it – for centuries. There is widespread agreement that ecosystems are "valuable" and that their value should be taken into consideration by individual and governmental decision makers, but differing interpretations remain (Daily, 1997). The term "value" implies the measurement of the extent to which people want or like a good or service (e.g. an ES). A distinction between "held" and "assigned" values has been proposed (Brown, 1984; Adamowicz *et al*., 1998) (see Annex 2 for a discussion of this distinction).

Types of value

The literature on environmental philosophy and ethics identifies three sets of values (Gagnon Thompson and Barton, 1994; Stern and Dietz, 1994; Oelschlaeger, 1997; Callicott, 2004):

1. instrumental and intrinsic values;
2. anthropocentric and biocentric (or ecocentric) values; and
3. utilitarian and deontological (or duty-generating) values.

The **instrumental value** of an ES is the value derived from the usefulness of the ES in achieving a given goal. For example, if a woodlot provides a certain community with woodfuel or food it has an instrumental value for that community. **Intrinsic value**, on the other hand, is the value that exists independently of any usefulness and reflects the value of something for its own sake. In other words, intrinsic value is the value of something unrelated to its instrumental use; it is also referred to as "non-instrumental" value. For example, if natural mangrove forests have intrinsic value, that value is independent of whether humans directly or indirectly use the forests, such as for recreation, as a source of goods (e.g. woodfuel, honey and wax) and inspiration, or for biodiversity conservation.

Anthropocentric value is centred on the idea that only humans can assign value. Thus, the value of other goods and services is instrumental to human goals; that is, it stems from the usefulness of those goods and services to humans. **Biocentric (or ecocentric) values** build on a non-anthropocentric view, assuming that certain goods and services have value, even if no human thinks so. For example, a biocentric value can be assigned to a certain wild species, even though no human thinks it is valuable. Instrumental and intrinsic values can be anthropocentric or non-anthropocentric.

Utilitarian values stem from the ability to provide "welfare"; that is, they are viewed as a means toward the end result of increased human welfare, as defined by human preferences, without any judgment about whether those preferences are good or bad. Existence value (see the concept of total economic value discussed below) is an example of a utilitarian (and anthropocentric) value: people might attribute value to a certain good or service just because it exists and regardless of its use. Existence value reflects the desire by some individuals to preserve and ensure the continued existence of certain species (e.g. the Royal Bengal tiger) or environments. On the other hand, **deontological values** imply a set of rights that includes a right to existence. Thus, something with intrinsic value would be viewed as irreplaceable, meaning that its loss cannot be offset or "compensated" by more of something else. For example, a person's own life is of intrinsic value to that person because it cannot be offset or compensated by that person having more of something else (Heal *et al.*, 2005).

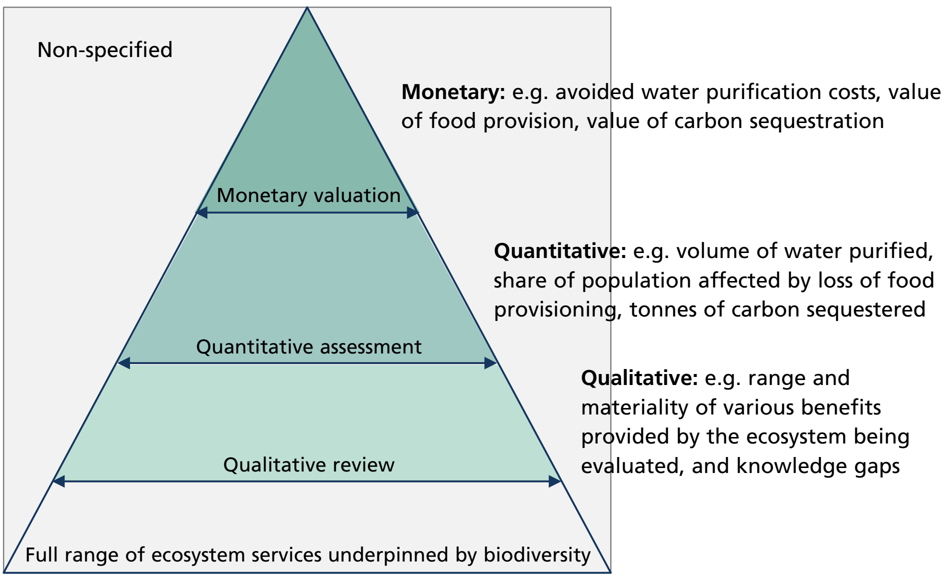
Valuation

Valuation is the process of attributing a value (either economic or non-economic) to something. The aim of economic valuation is to measure, in monetary terms, people's preferences for the benefits they obtain from, for example, ecosystem processes (TEEB, 2010a). Non-economic valuation often examines how the opinions of people are shaped or their preferences articulated, mostly beyond monetary terms. Even though non-economic valuation could be helpful in informing policy choices, this manual is confined to economic valuation (Animon, Matta and Pettenella, forthcoming).

The fact that ecosystems are valuable should encourage decision makers – ranging from individuals to governments – to take them into account in their decisions. Recognition that ecosystems and ESs are valuable is only an initial step; quantifying the value is likely to be more persuasive in decision making.

ESs may be measured and assessed in various ways and according to various metrics, which are broadly either qualitative, quantitative or monetary (Figure 7). Qualitative analysis generally focuses on non-numerical information, quantitative analysis involves numerical data, and monetary analysis translates quantitative data into currency values (TEEB, 2009). The type of metric used depends largely on the benefit being measured, the time and resources available and the significance of the decisions to be made. As shown in Figure 7, valuing all ESs in monetary terms might be difficult. For example, only a small subset of ecosystem processes and components are priced and incorporated in transactions as commodities or services (Pascual and Muradian, 2010). Difficulties exist in quantifying most ESs in terms that are comparable with the services obtained from human-made assets (Costanza *et al.*, 1997). Economics is about choice, and every decision is preceded by the weighing of values among alternatives (Bingham *et al.*, 1995). Measurement in monetary terms provides estimates of values in comparable units to enable the assessment of trade-offs and to demonstrate the importance of certain ESs (DEFRA, 2007). The logic behind ecosystem valuation, therefore, is to unravel the complexities of socio-ecological relationships, make explicit how human decisions would affect ES values, and express such changes in value in units (e.g. monetary) that allow their incorporation in public decision-making processes (Mooney, Cooper and Reid, 2005). Natural resource management decisions based on comparisons of benefits and costs are likely to be biased, however, when only a few ESs have clearly defined monetary value (Krieger, 2001).

FIGURE 7
The benefits pyramid for ecosystem services



Source: TEEB (2009).

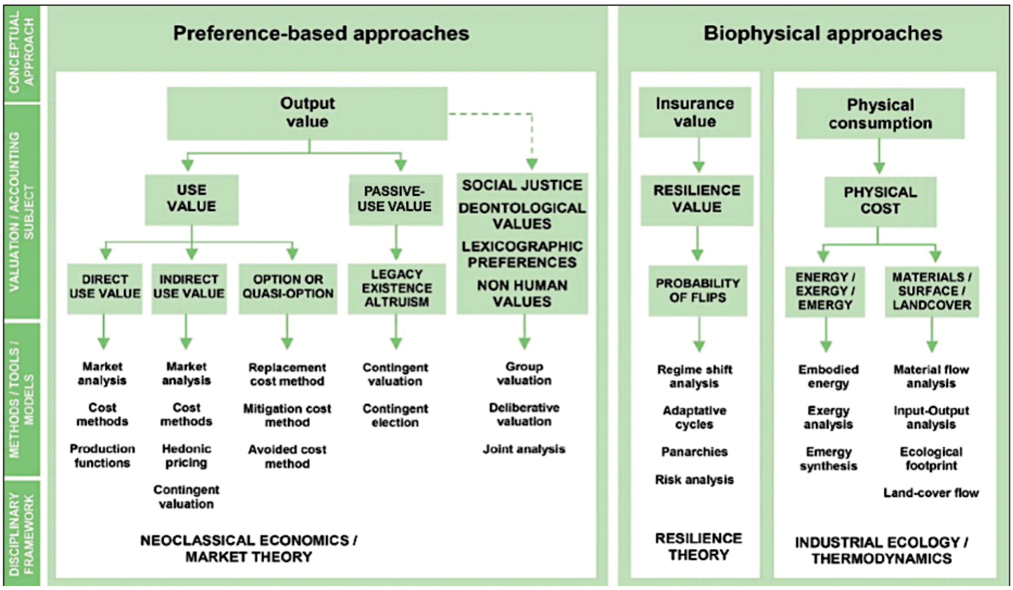
Valuation methods may be **biophysical** or **preference-based** (Gómez-Baggethun *et al.*, 2010; Pascual and Muradian, 2010) (Figure 8). The former have a "cost of production" perspective, meaning that they derive values from the measurement of the physical costs (e.g. labour, energy and material inputs) needed to produce a certain good or service. In ES valuation, this approach determines the costs involved in maintaining a given ecological state. Preference-based methods rely on models of human behaviour and centre around the idea that values arise from individual preferences and therefore are individual-based, subjective, context-based and state-dependent (Goulder and Kennedy, 1997; Nunes and van den Bergh, 2001).

The two valuation approaches – biophysical and preference-based – refer to different (but complementary) dimensions of ecosystem values. Biophysical methods address insurance value (Farber, Costanza and Wilson, 2002), also known as glue value (Fisher *et al.*, 2008; Gren *et al.*, 1994), which refers to ecosystem resilience (i.e. the capacity to remain in a given ecological state). This concept overlaps partly with the concept of supporting services, as identified in MEA (2005) (see section 2.1 of this manual).

Many challenges and limitations exist when valuing ecosystem resilience (Pascual and Muradian, 2010). For example, ecosystem transitions may be sudden and uncertain, making the valuation of ESs using marginal values impossible. This explains why current valuation efforts focus on preference-based methods, thus adopting a strongly anthropocentric vision that allows only a part of the total value of ecosystems to be estimated. These methods and vision build on the concept of total economic value (TEV).

FIGURE 8

Preference-based and biophysical approaches to the valuation of ecosystem services

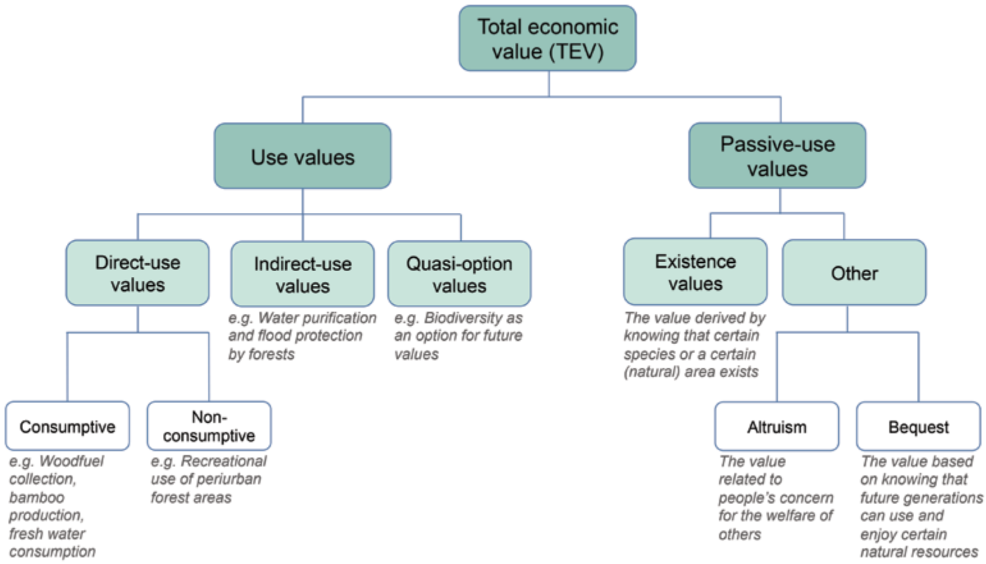


Source: Modified from TEEB (2010a).

Total economic value

Economic values can be categorized broadly as either use values or passive-use (sometimes also called non-use) values (Figure 9). The sum of both these values provides the TEV. **Use values** may be either direct or indirect. **Direct-use values** comprise those benefits derived from the actual, direct use of an ecosystem (such as a forest) and are normally distinguished as either consumptive (or extractive, implying the consumption/extraction of resources, such as the extraction of timber, woodfuel and non-wood products such as bamboo and medicinal herbs) or non-consumptive (or non-extractive, such as recreation activities, wildlife viewing, and enjoying the beauty of a landscape and scenery in a certain area). **Indirect-use values** refer to the benefits derived from an ecosystem's functions without direct interaction with it – such as watershed protection, water quality and purification, carbon sequestration, protection against natural hazards (e.g. floods), and pollination.

FIGURE 9
Total economic value and its components



Source: Modified from Mavsar and Varela (2014).

Quasi-option values[13] are those benefits derived from the option of directly or indirectly using forests in the future. Examples include considering a certain ecosystem as a potential source of future recreation opportunities, environmental study, timber and woodfuel, and biodiversity conservation. For example, existing biodiversity might be a source of active agents against future human diseases and agricultural pests. In this case, the quasi-option value of biodiversity conservation would be a kind of insurance premium paid today to reduce potential losses due to future adverse events (Bulte *et al.*, 2002).

Passive-use (or non-use) values are values unassociated with actual use. One type of passive-use value is existence value, which comprises the benefits derived from knowledge of the existence of a particular environmental feature or characteristic, such as biodiversity. For example, some people might value the Royal Bengal tiger or the Amazon forest just because it exists, even though they will never make direct use of such resources. Other types of passive-use value are **altruism** and **bequest** – that is

[13] Option value is a passive-use value, but quasi-option value is a use value that relates to the possibility of new future uses

the benefits derived from placing a value on the conservation of a certain environmental feature for other people (altruism) and future generations (bequest). Altruism value is the value assigned to people's concern for the welfare of others. Bequest value reflects the satisfaction that people derive from knowing that an environmental feature will be maintained so that future generations will have access to them.

In general, measuring indirect-use values poses greater challenges than measuring direct-use values. The assessment of option and passive-use values is even more challenging because the values cannot be measured directly and must be inferred from choices, behaviours or surveys.

Table 2 illustrates the links between various ES categories, as defined by CICES, and TEV components. Note that ESs may be valued in sets that address more than one TEV component. Note also that although the TEV framework is used, this does not imply that only monetized estimates of value can be used.

TABLE 2. **Categories of ecosystem services, according to the Common International Classification of Ecosystem Services, and associated components of total economic value**

Ecosystem services according to the Common International Classification of Ecosystem Services			Components of total economic value				
			Use values			Passive-use values	
Section	Division	Class	Direct use	Indirect use	Quasi-option use	Existence	Bequest and altruism
Provisioning	Nutrition	Cultivated crops	X		X		X
		Reared animals and their outputs	X		X		X
		Wild plants, algae and their outputs	X		X		X
		Wild animals and their outputs	X		X		X
		Plants and algae from *in situ* aquaculture	X		X		X
		Animals from *in situ* aquaculture	X		X		X
		Surface water for drinking	X		X		X
		Groundwater for drinking	X		X		X
	Materials	Fibres and other materials from plants, algae and animals for direct use or processing	X		X		X
		Materials from plants, algae and animals for agricultural use	X		X		X
		Genetic materials from all biota	X		X		X
		Surface water for non-drinking purposes	X		X		X
		Groundwater for non-drinking purposes	X		X		X

Table 2 continues on next page

Table 2 continued

Ecosystem services according to the Common International Classification of Ecosystem Services			Components of total economic value				
			Use values			Passive-use values	
Section	Division	Class	Direct use	Indirect use	Quasi-option use	Existence	Bequest and altruism
Provisioning	Energy	Plant-based resources	X		X		X
		Animal-based resources	X		X		X
		Animal-based energy	X		X		X
Regulating and maintenance	Mediation of waste, toxics and other nuisances	Bioremediation by microorganisms, algae, plants and animals		X	X		X
		Filtration/sequestration/ storage/accumulation by microorganisms, algae, plants and animals		X	X		X
		Filtration/sequestration/ storage/accumulation by ecosystems		X	X		X
		Dilution by atmosphere, freshwater and marine ecosystems		X	X		X
		Mediation of smell/noise/ visual impacts		X	X		X
	Mediation of flows	Mass stabilization and control of erosion rates		X	X		X
		Buffering and attenuation of mass flows		X	X		X
		Hydrological cycle and water-flow maintenance		X	X		X
		Flood protection		X	X		X
		Storm protection		X	X		X
		Ventilation and transpiration		X	X		X
	Maintenance of physical, chemical and biological conditions	Pollination and seed dispersal		X	X		X
		Maintenance of nursery populations and habitats		X	X		X
		Pest control		X	X		X
		Disease control		X	X		X
		Weathering processes		X	X		X
		Decomposition and fixing processes		X	X		X
		Chemical condition of fresh waters		X	X		X
		Chemical condition of salt waters		X	X		X
		Global climate regulation by reduction of greenhouse gas concentrations		X	X		X
		Micro and regional climate regulation		X	X		X

Table 2 continues on next page

Table 2 continued

Ecosystem services according to the Common International Classification of Ecosystem Services			Components of total economic value				
Section	Division	Class	Use values			Passive-use values	
			Direct use	Indirect use	Quasi-option use	Existence	Bequest and altruism
Cultural	Physical and intellectual interactions with ecosystems and landscapes/ seascapes [environmental settings]	Experiential use of plants, animals and landscapes/ seascapes in different environmental settings	X	X	X		X
		Physical use of landscapes/ seascapes in different environmental settings	X	X	X	X	X
		Scientific	X	X	X	X	X
		Educational	X	X	X	X	X
		Heritage, cultural	X	X	X	X	X
		Entertainment	X	X	X	X	X
		Aesthetic	X	X	X	X	X
	Spiritual, symbolic and other interactions with ecosystems and landscapes/ seascapes [environmental settings]	Symbolic	X	X	X	X	X
		Sacred and/or religious	X	X	X	X	X
		Existence	X	X	X	X	X
		Bequest	X	X	X	X	X

Source: Modified from Haines-Young and Potschin (2011a); Pascual and Muradian (2010).

2.3 FOREST RESOURCES AND FOREST-BASED ECOSYSTEM SERVICES IN BANGLADESH

In Bangladesh, land gazetted[14] as forest land covers about 2.6 million ha, which is roughly 18 percent of the country's land area (Bangladesh Forest Department, 2017). Much of this land is no longer covered by forests, however: according to FAO's Global Forest Resources Assessment (FAO, 2015), natural forests cover 1.43 million ha. Trees outside forests – mainly comprising homesteads – cover about 2.4 million ha, and there are 0.07 million ha of planted forests, consisting of plantations along roadsides, railways and water channels (Bangladesh Forest Department, 2017).

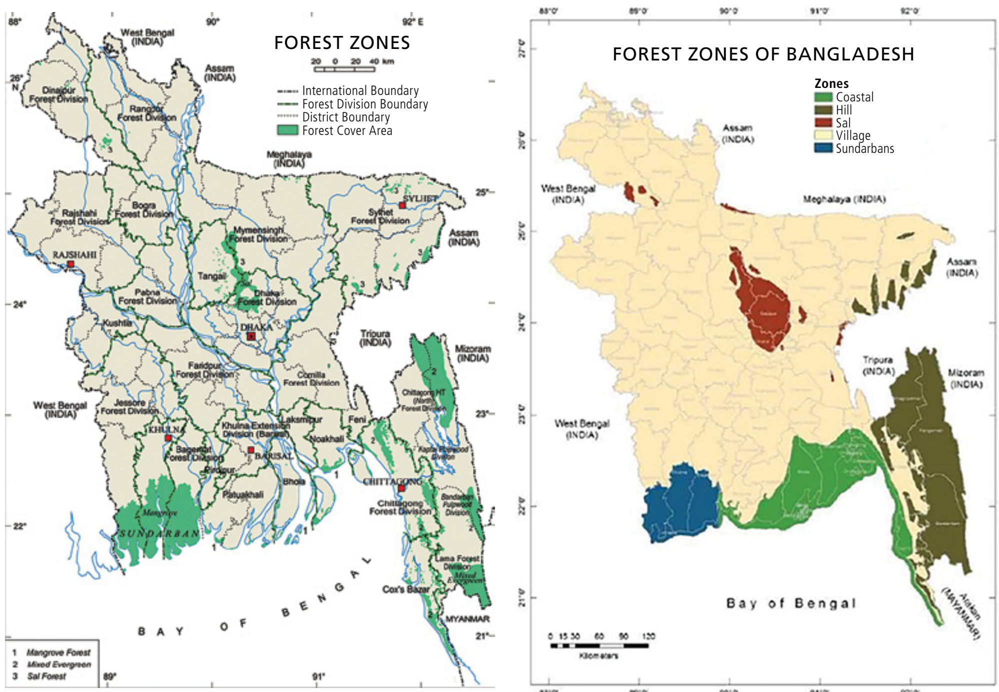
Forests in Bangladesh occur in five main zones (Chowdury, 2014) (Figure 10):

1. *Sundarbans* – the world's largest contiguous mangrove forest, covering about 0.6 million ha in the southwest of the country (India hosts another 0.4 million ha of mangrove forests in the same ecological zone).

[14] Land declared by the government as forest through notification in the government gazette is legally identified as forest.

2. *Coastal forests* – covering about 0.2 million ha on the coast of southern Bangladesh. These forests are the result of afforestation and reforestation with species such as keora (*Sonneratia apetala*) and goran (*Avicennia officinalis*).
3. *Hill forests* – about 0.7 million ha of tropical evergreen and semi-evergreen forests in the southeast and east of Bangladesh (e.g. Chittagong, Chittagong Hill Tracts, Cox's Bazar and Sylhet). These forests were degraded and have been supplemented with plantations.
4. *Sal forests* – tropical moist deciduous forests in the central and western parts of the country in which sal (*Shorea robusta*) is the dominant tree species. These forests cover about 0.12 million ha and are largely degraded and fragmented into small patches.
5. *Village forests* – consisting of trees grown around homesteads in rural areas of Bangladesh. Such forests are privately owned, and they play crucial roles in the economies of rural households and communities as the main source of timber, woodfuel and bamboo.

FIGURE 10
Bangladesh forest area (a) and forest types and zones (b)



(a) **(b)**

Source: Modified from FAO (2015).

Figure 11 shows examples of ESs provided by forests in Bangladesh.

FIGURE 11
Examples of ecosystem services delivered by forest ecosystems in Bangladesh

PROVISIONING ECOSYSTEM SERVICES (ESs)

(a) Timber
(b) Fuelwood
(c) Thatching materials

REGULATING ESs

(d) Watershed regulation
(e) Coastal protection
(f) Carbon sequestration

CULTURAL ESs

(g) Scenic beauty
(h) Wilderness

Source: (a), (b), (d), (e), (g) and (h) © Sepul Kanti Barua; (c) and (f) © Falgoonee Kumar Mondal

Reflection point

Make a list of the main ecosystems present in the region in which you are working, select at least one of these, and identify all the ESs it provides. List the ESs according to CICES. Based on your knowledge of the regional context, discussions with colleagues, and other available information (e.g. published and unpublished literature):

- Estimate the state of each identified ES in the range of 1–5 (where 1 = extremely poor and 5 = extremely good).
- Indicate the regional trend – decreasing, stable or increasing – for each identified ES over the previous ten years (or another timespan, as defined by you).
- For each ES, indicate the component(s) of the TEV that might apply.
- Report your findings according to the example below and discuss with your colleagues.

Table 3 presents a hypothetical example of the state of ESs in a natural forest.

TABLE 3. **The state of ecosystem services in the ABC Forest District**

Ecosystem service (ES) according to the Common International Classification of Ecosystem Services			**Current state of ES 1 (extremely poor) 5 (extremely good)**		**Trend in state of ES over the previous ten years: decreasing (D) stable (S) increasing (I)**		**Total economic value components**
Section	Division	Class	State	Notes	Trend	Notes	
Provisioning	Food	Wild animals and their outputs Wild plants, algae and their outputs	2	Limited forest area, accessible to local communities for hunting and the collection of herbs and fruit Some endemic herb and fauna species – largely used in local traditional meals and ceremonies – are at risk	D	Game, herbs and wild fruit have decreased due to the conversion of large forest areas to industrial timber plantations using fast-growing species as a result of forest concession agreements	Consumptive direct-use value Existence value
Provisioning	Materials	Fibre and other materials from plants, algae and animals for direct use or processing	5	Production of industrial roundwood assortments	I	Increased timber production from plantations of fast-growing species	Consumptive direct-use value
Provisioning	Energy	Plant-based materials	2	Limited forest area accessible to local communities for woodfuel collection	D	The supply of woodfuel has decreased due to the conversion of large forest areas into industrial timber plantations using fast-growing species as a result of forest concession agreements (production of wood assortments for industrial processing)	Consumptive direct-use value

Notes: Selected ecosystem = natural forest. This is a hypothetical situation.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Module 3 The basics of cost–benefit analysis

KEY MESSAGES

- Making good decisions requires the ability to evaluate policy/project scenarios using meaningful units of measurement that enable comparisons among the various costs and benefits over time.
- The concept of the "time value of money" is that the same amount of money may have different values depending on when it is available for consumption. Money now may be worth more than in the future because the future is uncertain and because we expect to earn more in the future. *Discounting* is a procedure to enable the comparison of values occurring at different times.
- Financial and economic analyses enable us to assess the economic feasibility of a project and to judge efficiency in the allocation of resources.
- Financial analysis considers market prices, and economic analysis also takes into consideration values that are not marketed (e.g. the costs and benefits associated with water pollution, biodiversity loss, changes in air quality, and soil protection).
- Cost–benefit analysis (CBA) is a methodological tool for performing financial and economic analyses of projects or investments based on an analysis of the associated costs and benefits. In particular, CBA uses discounted cashflows to calculate profitability and risk indicators that allow the assessment of single investments as well as comparisons of alternative investment options.
- Profitability indicators include the net present value, benefit/cost ratio and internal rate of return. The payback period is used as a risk indicator. Risks and uncertainties associated with CBA can also be addressed through sensitivity analyses that check how CBA results vary when variables (e.g. certain costs and benefits, and discount rates) change.
- The choice of discount rate is crucial because it can significantly affect the CBA. In Bangladesh, the General Economics Division of the Planning Commission, Ministry of Planning, advises ministries and other governmental bodies to use a 15 percent discount rate when preparing development project proposals. Other governments recommend other discount rate values (e.g. 12 percent in the Philippines and India and 15 percent in Pakistan). The Asian Development Bank uses a 10–12 percent discount rate in the assessment of projects.

To use and understand economic valuation methods and to further develop and analyse their outcomes, familiarity is needed with some basic concepts of financial economics. One of these is the "time value of money", which is the concept that the same amount of money may have different value depending on when it is available for consumption. Cost–benefit analysis (CBA) is a tool used in financial and economic analyses to help decision making and project planning. This module explains how to deal with the "time value of money" by moving value forward or back in time, and how to perform a CBA in practice.

3.1 TIME VALUE OF MONEY

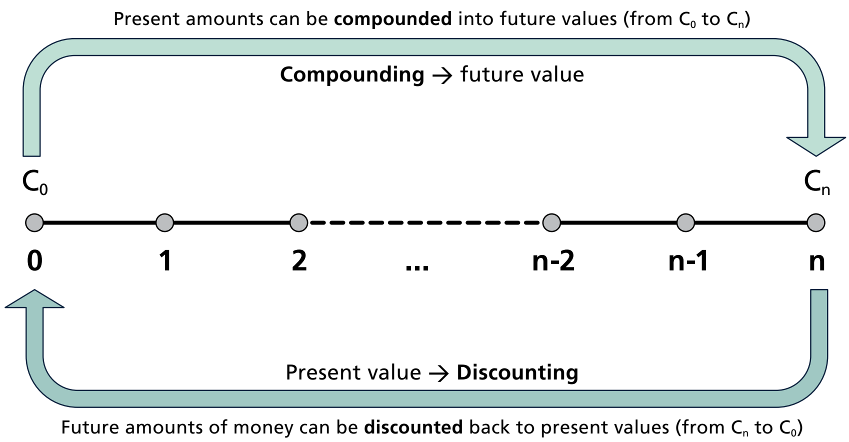
The common expression, "a dollar today is worth more than a dollar tomorrow" reflects what, in financial mathematics, is usually stated as "the time value of money" – that is, the idea that the same amount of money may have different value depending on when it is available for consumption. People tend to prefer money today: if the money is only available "tomorrow" we would have to postpone consumption, thereby making tomorrow's dollar less valuable than today's.

This section discusses the valuing of money over various periods, including the present value of future money and the future value of present money. The focus is on present value – that is, discounting.

Compounding and discounting

To compare values occurring at different times (e.g. years), they can be moved either "forward" to compute future values or "backward" (i.e. to the present) to determine present values. The former procedure is called **compounding** and the latter is called **discounting** (Figure 12). Discounting is used to compare costs and benefits that occur at different moments in time. The discount rate has two components: time preference in consumption (because the future is uncertain, what can be consumed today has more value); and the fact that future values are worth less because people expect their incomes to grow.[15]

FIGURE 12
Compounding and discounting



[15] See Boscolo, Vincent and Panayotou (1998) for details.

Through compounding it is possible to compute future values using the following general formula:

$$C_n = C_0 \times (1+r)^n \qquad (1)$$

where:

C_n = future value at year n

C_0 = value at present year

r = interest rate

n = time (number of years).

If $(1 + r) = q$, the equation can also be stated as:

$$C_n = C_0 \times q^n \qquad (2)$$

For example, a deposit of USD 100 at a compound interest rate of 2 percent per year for five years would correspond to a future value after five years (C_5) of:

$C_5 = 100 \times (1+0.02)^5$

That is, $C_5 = 100 \times (1.02)^5$

Thus, $C_5 = USD\ 110.41$

Conversely, using discounting it is possible to compute present values by inversing equation (1):

$$C_0 = \frac{C_n}{(1+r)^n} \qquad (3)$$

This can also be notated as:

$$C_0 = C_n \times q^{-n} \qquad (4)$$

Consider, for example, that an investor wants to know how much to invest now to obtain USD 100 in five years' time at a compound interest of 2 percent per year. This would correspond to a present value (C_0) given by:

$C_0 = \frac{100}{(1+0.02)^5}$

That is, $C_0 = \frac{100}{(1.02)^5}$

$C_0 = USD\ 90.57$

Thus, the investor would need to invest USD 90.57 to obtain USD 100 in five years' time at an interest rate of 2 percent per year. The factor $1 \div (1+r)^n$, or $1 \div q^n$, is known as the **discount rate**.

When performing economic assessments of a proposed project, reference is usually made to present values. Thus, all values in cashflows are discounted to the present at an appropriate discount rate (section 3.4 addresses the choice of discount rate).

These compounding and discounting procedures are for single amounts. This suffices for an understanding of the rationale of CBA (see section 3.2) and its implementation.[16]

3.2 FINANCIAL AND ECONOMIC ANALYSES

Financial and economic analyses help in assessing projects for investment and thus contribute to decision making. Such analyses also ensure the efficient allocation of resources by showing the benefit of implementing a particular project rather than alternatives; this is part of investment analysis and helps determine the technical and institutional feasibility of projects (IFAD, 2014). Financial and economic analyses performed during project development can help identify the best technical and institutional options.

CBA plays a prominent role in financial and economic analyses. Other tools include cost-effectiveness analysis and multicriteria analysis (Box 3), which might be used when the benefits of an investment are difficult to measure or are not measurable in monetary terms (e.g. the benefits are intangible, such as community empowerment or increased access to assets or services) and therefore cannot be taken into account in CBA.

BOX 3

Cost–benefit analysis, cost-effectiveness analysis and multicriteria analysis

Cost–benefit analysis (CBA) is a methodological tool for performing financial and economic analyses of investment projects based on the analysis and comparison of the expected costs and benefits. CBA uses discounted cashflows to calculate profitability and risk indicators that allow the assessment of single investments and comparisons of alternative investment options (even in different sectors). This module provides detailed information on CBA indicators.

Cost-effectiveness analysis (CEA) is used to assess the costs and outcomes or effects associated with an investment and to identify the least-costly option that will achieve the same result. CEA is usually used when the benefits of an investment are difficult to quantify or are difficult to estimate in monetary terms but the costs can easily be identified. CEA can also be used to compare alternative investments sharing the same objectives. The main limitations are that it is not possible to make comparisons among investments with different objectives and that outcomes are not considered in monetary terms.

Multicriteria analysis (MCA) is used for comparing investments and managing complex decision problems when the options entail many different objectives. MCA allows the consideration of multiple – including non-financial and non-economic – aspects or criteria. Criteria that vary according to scale or range can be weighted to normalize results. Outcomes do not need to be expressed in monetary terms. MCA allows the analysis of the effects of different assumptions; it can also rank options and discriminate between acceptable and unacceptable options. A limitation is that outcomes are not expressed in monetary terms; another is that assumptions about criteria and weights are subjective.

Source: IFAD (2014).

[16] Annex 3 summarizes some key financial mathematical formulas that can be used in economic valuations.

This manual focuses on CBA, which is commonly used to facilitate investment decisions. Because project benefits – or, in pure financial terms, revenues – and costs rarely all occur at the same time, discounting is applied to project cashflows (where a cashflow comprises the records of costs and benefits associated with a given project).

Cashflows need to be discounted appropriately to perform CBA. Specific indicators can then be computed to assess the profitability and risk associated with a given project.

Section 3.3 explains the rationale and meaning of profitability indicators. Before moving to indicators, however, it is important to highlight the difference between financial and economic analyses. In **financial analysis,** all costs and revenues are valued according to their market prices; thus, only cash inflows and outflows are taken into account. **Economic analysis** builds on financial analysis to take into account the costs and benefits not captured in the financial analysis. In other words, economic analysis also considers non-market impacts – that is, any positive or negative externality deriving from a project (IFAD, 2014), such as in terms of increased or reduced ESs or environmental quality. For example, the financial costs of a new afforestation project include all costs incurred in implementation, such as those associated with seedling production, irrigation, fertilizers, machinery and labour. The revenues of the project comprise the money derived from timber sales, taking into account the market prices of the expected assortments. Additional benefits might also arise, however, such as those associated with carbon sequestration, the creation of new habitats for biodiversity, and increased pollination (potentially with positive impacts on nearby agricultural production). Such benefits are not accounted for in a financial analysis because they do not provide market revenues, but they should be part of an economic analysis.

Building on the financial analysis, an economic analysis can be performed in one of two ways:

1. A **traditional economic analysis** considers the same costs and benefits covered in the financial analysis (but not taxes, duties and subsidies). It adjusts these using appropriate coefficients (or conversion factors) with the aim of converting market prices to economic or shadow prices (Box 4) to reflect the social value of goods by taking into account any distortions that might affect market prices. For example, although wages normally have a well-known financial (i.e. market) value, the market wage for unskilled labour (e.g. in agriculture) does not appropriately reflect its surplus status, and hence its lower opportunity cost. The computation of the shadow price in this case involves an adjustment by a percentage that usually ranges between 50 percent and 80 percent of the market wages.
2. An **extended economic analysis** considers those costs and benefits (externalities) not covered by a financial analysis. Assume, for example, that a decision has been made to conserve a highly valuable natural forest area through strict conservation and set-aside measures. This might produce positive externalities (benefits) in terms of biodiversity conservation, landscape amenity, soil conservation, carbon sequestration and increased recreational/tourism potential. On the other hand, the decision might have negative impacts (costs) by reducing the access of local communities to timber, woodfuel and forest foods and thereby reducing food security and affecting the diet and health of local people.

BOX 4
Shadow prices

Shadow prices are the implicit prices that would exist in efficiently working markets. In an economic analysis, market (i.e. financial) prices are converted to economic – "shadow" – prices using conversion coefficients as a way of reflecting the social opportunity cost of goods and accounting for distortions (e.g. trade barriers). For example, the unit market (financial) value of unskilled labour – that is, the unit market value of a wage for a unskilled workers – might be USD 100 in a given area. Assuming that the area is characterized by a labour surplus, the market wage needs to be adjusted into a shadow price for unskilled labour by considering an appropriate conversion factor (e.g. 0.8). The economic value of wages for unskilled labour would be then 80 percent of the observed market wages.

In a similar way, duties on imported goods procured as inputs for a project might mean that the market price overestimates the social value of the goods, and a conversion coefficient can be used to correct for this. If duties comprise about 10 percent of the value of the goods, the conversion coefficient would by 0.9.

The following spreadsheet provides an example of financial and economic cashflows for labour and imported goods:

currency: 1 000 US$		Years									
	Conversion coefficients	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Financial cash-flow											
Costs											
Labor	1	30	30	25	25	25	18	18	18	15	15
Imported inputs	1	50	50	42	42	42	35	35	35	20	20
Total		**80**	**80**	**67**	**67**	**67**	**53**	**53**	**53**	**35**	**35**
Economic cash-flow											
Costs											
Labor	0.8	24	24	20	20	20	14.4	14.4	14.4	12	12
Imported inputs	0.9	45	45	37.8	37.8	37.8	31.5	31.5	31.5	18	18
Total		**69**	**69**	**57.8**	**57.8**	**57.8**	**45.9**	**45.9**	**45.9**	**30**	**30**

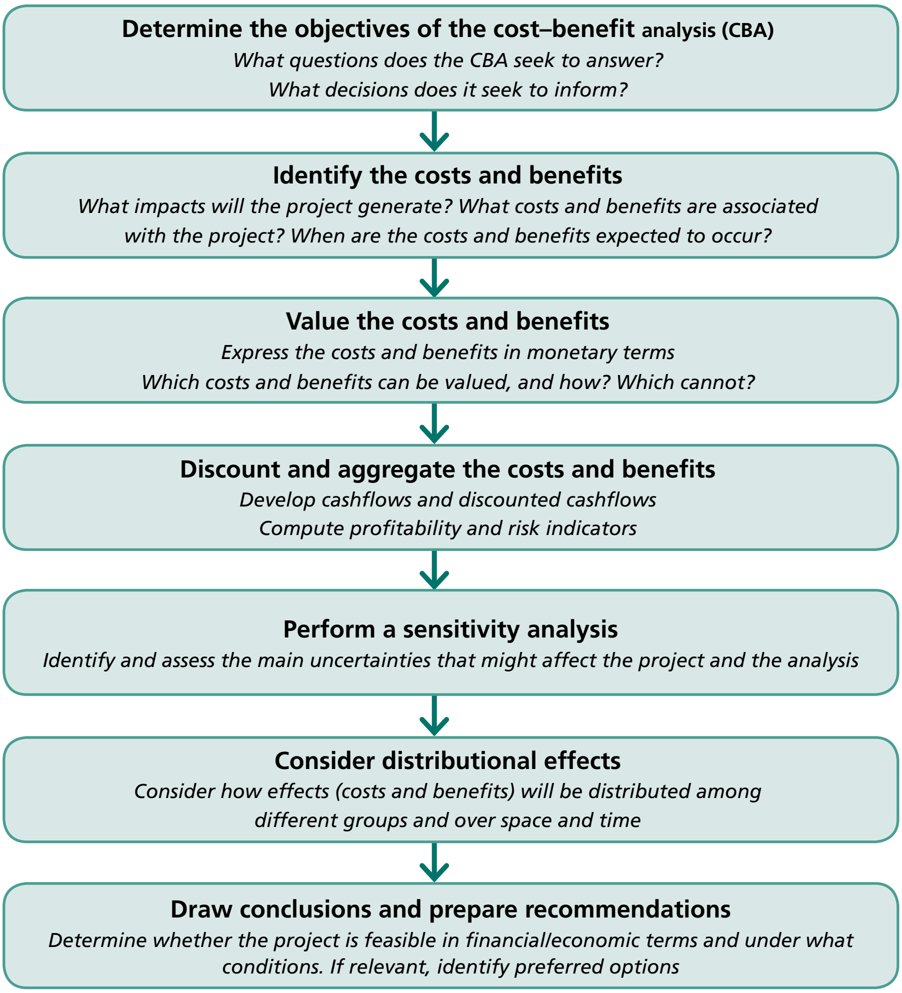
Adjusted economic value for imported inputs:
50 x 0.9 = 45

Adjusted economic value for labor:
30 x 0.8 = 24

Steps in cost–benefit analysis

Figure 13 shows the steps involved in CBA. The sequence may vary, but practitioners can use the figure as a general reference framework. Each step is described below.

FIGURE 13
The main steps in conducting cost–benefit analyses



Source: Modified from Buncle *et al.* (2013).

1. Determine the objectives

Determining the objectives of the CBA implies confirmation of the underlying problem and its links with the proposed project. It also involves clarifying the decision the CBA is expected to inform and therefore what the analysis should achieve.

2. Identify the costs and benefits

Identifying the costs and benefits associated with each project option under consideration usually involves the adoption of a **with/without** project approach. The "business as usual" (BAU) option is assessed first to determine how the situation would evolve if the project was not implemented. The BAU situation is then compared with the proposed project options. In so doing, analysts look for the incremental benefits (or costs) that would be generated by each project option – that is, the value-added of each option compared with the BAU situation. The with/without project approach is not the same as a before/after project analysis because it is not just about comparing changes between two points in time. The "without project" scenario is likely to change over time because of the dynamic nature of natural and anthropic systems.

The inputs and outputs identified for the "with" and "without" scenarios are converted to costs and benefits. Inputs are costs by definition. Outputs and outcomes qualify as benefits if they are positive and count as costs if they are negative.

3. Value the costs and benefits

The costs and benefits identified in the previous step need to be translated into monetary values to the extent possible. This is normally relatively easy for costs and revenues with market values (prices). It might be problematic (and sometimes even impossible) for externalities, however, in which case various valuation methods and approaches can be used; these are presented in detail in module 4, and modules 5–7 provide examples.

4. Discount and aggregate the costs and benefits

The various costs and benefits of a project option might occur at different times. To enable comparisons and to develop cashflows, therefore, their values need to be converted to present (i.e. discounted) values using an appropriate discount rate (see section 3.4) and formula 3 (given in section 3.1). The calculation of discounted cashflows enables the computation of profitability indicators (see section 3.3).

5. Sensitivity analysis

A sensitivity analysis is performed to check the robustness of the CBA results; it addresses the main risks and uncertainties that could affect the proposed project.

Sensitivity analysis consists of performing several CBAs with differing underlying assumptions. In particular:

- Project variables with the most uncertainty are identified first (e.g. labour cost; the presence of subsidies; and the planting success rate).
- Realistic ranges are assigned to accommodate the potential variation (positive and negative) in these variables.

- The impacts of changes in variables are assessed by considering changes in profitability indicators.

Sensitivity analyses can also be performed using different discount rates (e.g. ± 2 percent variations of the originally used rate) to assess the extent to which this affects the feasibility of the project or the ranking of project options.

Section 3.5 provides additional information on risk, uncertainty and sensitivity analysis.

6. Distributional effects

Profitability indicators provide information on the absolute and relative performance of project options, but they do not provide information on distributional effects – in other words, they are not informative about who incurs the costs and who enjoys the benefits or about how costs and benefits are distributed in space and time.

The distribution of costs and benefits among stakeholder groups can be addressed through benefit/cost mapping exercises, which involve the development of matrices that link benefits and costs to affected groups. Based on the outcomes of the mapping exercise, it might be possible to make adjustments in the distribution to address concerns about equitability and feasibility and to ensure that target groups benefit appropriately.

7. Conclusions and recommendations

CBA results and outcomes are generally presented in a report that summarizes the key steps taken in performing the analysis and draws appropriate conclusions. Based on CBA outcomes, analysts can determine whether a project is financially and economically viable and the conditions that may affect such viability. The report may identify thresholds for key parameters that determine project viability. It might also compare the financial and economic performance of project options (e.g. considering profitability and risk indicators) as a way of assisting selection.

Based on the outcomes of the CBA, analysts may propose changes to project design and make recommendations for developers and decision makers.

3.3 PROFITABILITY INDICATORS

Profitability indicators are used to assess projects and support decision making by providing information on the efficiency of projects and their capacity to generate value. By so doing, such indicators allow the comparative analysis of project options and comparisons between proposed projects and BAU.

Profitability indicators include:

- net present value (NPV);
- internal rate of return (IRR); and
- benefit/cost ratio (B/C).

Net present value

The NPV of a given project is the present value of the net cashflow associated with it; it is the sum, therefore, of all discounted costs and benefits. The NPV indicates the amount the project will "earn". If the NPV is negative, the costs outweigh the benefits and the project is not viable.

Absolute profitability is attained if a project's NPV is greater than zero. Relative profitability is achieved when a project's NPV is higher than the alternative (such as another project, or BAU). In general terms, therefore, it is desirable that the NPV is positive and as high as possible. This implies that, in comparing the NPVs of alternative projects, the higher of the NPVs should be preferred.

NPV provides information on the absolute net value generated by a given project; its focus is on maximizing the project's value but it is not informative on its efficiency. Thus, NPV should never be used as a stand-alone profitability indicator; rather, it should be combined with additional, complementary indicators or measures (such as IRR and the B/C ratio) that address efficiency. Box 5 provides an example of NPV calculation based on the cashflows of two project options.

BOX 5

Calculating net present value

The net present value (NPV) of two projects, A and B, needs to be calculated to determine which is most profitable. The cashflows of the two projects should first be discounted (see section 3.1). In this case, a discount rate ("r" in the tabulation) of 5 percent is used. Once all benefits and costs have been discounted, the NPV is calculated as the difference between the sum of the discounted benefits and the sum of the discounted costs. In the example, project A has the higher NPV and should therefore be preferred, all else being equal.

The NPV can be computed manually, as described above, or by using the formula available in Microsoft Excel. The Excel formula for calculating the NPV for project A is:

=NPV(L2, D5:D9)+D4

Where:

- L2 is a cell reporting the discount rate (in this case 5 percent).
- D5:D9 is the range of cells containing the undiscounted net cashflow, with the exception of the net cashflow for year 0.
- D4 is the cell reporting the undiscounted net cashflow for year 0.

The formula for calculating the NPV for project B is:

=NPV(L2; I5:I9)+I4

Box 5 continues on next page

Box 5 continued

The following spreadsheet shows the calculations:

r 5%

Project A: cash flow

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	30	-30
2	50	30	20
3	50	30	20
4	50	30	20
5	75	20	55
Total	*225*	*190*	*35*

Project B: cash flow

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	30	-30
2	0	30	-30
3	75	30	45
4	75	30	45
5	75	20	55
Total	*225*	*190*	*35*

Project A: discounted cash flow (r = 5%)

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	29	-29
2	45	27	18
3	43	26	17
4	41	25	16
5	59	16	43
Total	*188*	*172*	*NPV = 16*

Project B: discounted cash flow (r = 5%)

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	29	-29
2	0	27	-27
3	65	26	39
4	62	25	37
5	59	16	43
Total	*185*	*172*	*NPV = 13*

Internal rate of return

The IRR is the rate at which the discounted costs equal the discounted benefits (i.e. NPV becomes null, or zero). Also known as the discounted cashflow yield, the IRR is a measure of the rate of profitability expected from a project. It represents the maximum rate of interest earned on the year-by-year diminishing capital balance of an investment.

In other words, it is the maximum interest rate that a project could earn and not waste resources. The IRR of a given project can be compared with the IRR associated with other (i.e. alternative) projects: the project with the highest IRR would be ranked highest. The IRR can also be compared with a baseline or standard rate, for example the interest rate paid on ordinary investments, the interest rate for a commercial loan, or the rate paid for safe investments like state bonds. It is usually considered that absolute profitability is achieved if a project's IRR is higher than a given discount rate (e.g. the baseline discount rate used for discounting the cashflow). Relative profitability is achieved when a project's IRR is higher than the IRRs of alternatives.

Box 6 provides an example of IRR calculation based on the cashflows of the two project options used in the example in Box 5.

BOX 6

Calculating internal rate of return

The internal rates of return (IRR) of projects A and B (see Box 5) are to be calculated to determine which of the two is more profitable. Using the discounted cashflows of the two projects, this can be done manually by using an iterative procedure that calculates the net present value (NPV) with different discount rates (“r” in the tabulation) until the NPV becomes null, or by using the formula available in Microsoft Excel. The Excel formula for calculating the IRR for project A is:

=IRR(D4:D9; 0,01)

Where D4:D9 is the range of cells containing the undiscounted net cashflow over the project period and 0,01 is the “guess” value for the discount rate – that is, the value at which the system will start the calculations. This value can be omitted (in which case the system assumes that the value is 0,1).

The formula for calculating the IRR for project B is:

=IRR(DI4:I9; 0,01)

The project with the highest IRR should be preferred, assuming that the projects analysed are independent of each other and of the same length and magnitude. In this case, the IRR would be 11 percent for project A and 9 percent for project B; thus, project A should be preferred. The following spreadsheet shows the calculations:

r = 5%

Project A: cash flow

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	30	-30
2	50	30	20
3	50	30	20
4	50	30	20
5	75	20	55
Total	*225*	*190*	*35*

Project B: cash flow

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	30	-30
2	0	30	-30
3	75	30	45
4	75	30	45
5	75	20	55
Total	*225*	*190*	*35*

Project A: discounted cash flow (r = 5%)

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	29	-29
2	45	27	18
3	43	26	17
4	41	25	16
5	59	16	43
Total	*188*	*172*	*NPV = 16*
		IRR	*11%*

Project B: discounted cash flow (r = 5%)

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	29	-29
2	0	27	-27
3	65	26	39
4	62	25	37
5	59	16	43
Total	*185*	*172*	*NPV = 13*
		IRR	*9%*

Benefit/cost ratio

B/C is the ratio between discounted benefits and costs. Similarly to the IRR, the B/C focuses on efficiency rather than on maximizing a project's NPV. A B/C greater than 1 means that the discounted benefits exceed the discounted costs. In comparing project options, the one with the highest B/C should be preferred. Note that the project option with the highest B/C will also have the highest NPV. The B/C allows the ranking of project options, which is especially helpful when there are budgetary constraints.

Box 7 contains an example of B/C calculation based on the cashflows of the two project options used in the example in Box 5.

BOX 7

Calculating the benefit/cost ratio

The benefit/cost (B/C) ratios of projects A and B (see boxes 5 and 6) are to be calculated to determine which of the two is more profitable. This is done by dividing the sum of the discounted benefits by the sum of the discounted costs. The Microsoft Excel formula for calculating the B/C ratio for project A is:

=B20/C20

Where B20 is the cell containing the total discounted benefits for project A and C20 is the cell containing the total discounted costs for project A.

The formula for calculating the B/C ratio for project B is:

=G20/H20

Project A has a slightly higher B/C ratio and should therefore be preferred. The following spreadsheet shows the calculations:

r	5%

Project A: cash flow

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	30	-30
2	50	30	20
3	50	30	20
4	50	30	20
5	75	20	55
Total	*225*	*190*	*35*

Project B: cash flow

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	30	-30
2	0	30	-30
3	75	30	45
4	75	30	45
5	75	20	55
Total	*225*	*190*	*35*

Project A: discounted cash flow (r = 5%)

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	29	-29
2	45	27	18
3	43	26	17
4	41	25	16
5	59	16	43
Total	*188*	*172*	*NPV = 16*
		IRR	*11%*
		B/C	*1.09*

Project B: discounted cash flow (r = 5%)

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	29	-29
2	0	27	-27
3	65	26	39
4	62	25	37
5	59	16	43
Total	*185*	*172*	*NPV = 13*
		IRR	*9%*
		B/C	*1.08*

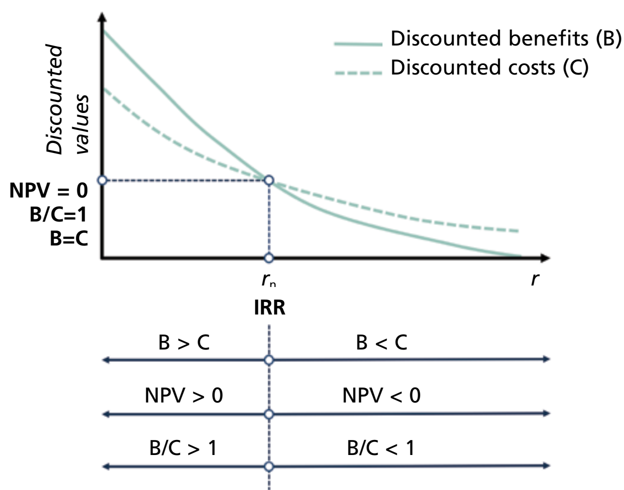
Table 4 summarizes the three profitability indicators (NPV, IRR and B/C ratio), and Figure 14 represents the relationships among these.

TABLE 4. **Summary of profitability indicators**

Indicator	Description	General formula	Interpretation
Net present value (NPV)	Present value of the net cashflow associated with a project: i.e. the sum of all discounted costs and benefits	$NPV = \sum_{t=0}^{n} \frac{(B-C)_t}{(1+r)^t}$	Provides information on the absolute net value generated by a given project. The option with the highest NPV should be preferred
Internal rate of return (IRR)	The rate at which the discounted costs equal the discounted benefits: i.e. the rate at which the NPV becomes null (0)	r that turns $NPV = \sum_{t=0}^{n} \frac{(B-C)_t}{(1+r)^t} = 0$	Provides information on the rate of profitability expected in a project. The option with the highest IRR should be preferred
Benefit/cost (B/C) ratio	The ratio of the discounted benefits to the discounted costs	$\frac{B}{C} = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} / \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$	Provides information on the efficiency of project options. The option with the highest B/C ratio should be preferred

Notes: In the formulas, B_t = benefits at time *t; C_t* = costs at time *t; r* = discount rate; *n* = project duration (e.g. number of years).

FIGURE 14
The relationship between net present value, internal rate of return and benefit/cost ratio



Note: NPV = net present value; IRR = internal rate of return; B/C = benefit/cost.

Normalization

Project options might differ in, for example, their timespan or spatial scale. When this is the case, performance indicators need to be normalized before they can be compared. Normalization means calculating indicators according to a common unit, such as a year or a hectare. Box 8 presents an example of normalizing the NPV.

BOX 8

Normalizing net present value

The following spreadsheet shows the cashflows for two project options (A and B):

	Project A Duration: 5 years; Size: 2.1 ha		**Project B** Duration: 7 years; Size: 0.2 ha	
Year	Benefits (B)	Costs (K)	Benefits (B)	Costs (K)
0	0.00	7 000.00	0.00	150.00
1	4 000.00	13 000.00	0.00	300.00
2	6 000.00	4 500.00	50.00	50.00
3	9 000.00	0.00	180.00	50.00
4	9 000.00	0.00	220.00	50.00
5			230.00	0.00
6			240.00	0.00

Assuming a discount rate (r) of 5 percent, the NPV for the two projects would be as follows:

- NPV_A = 967.98
- NPV_B = 175.75.

Project A apparently has a higher relative profitability because it has a higher NPV. The two projects have different timespans and sizes, however. To enable a proper comparison, the NPVs need to be normalized by:

- time (i.e. NPV/year)
- area (i.e. NPV/ha).

The two NPVs refer to the same year (i.e. year 0). The NPV is the present value of a terminating annual series; thus, the annual NPV corresponds with single annuities (a) according to the following formula:

$$a = NPV \frac{rq^n}{(q^n - 1)}$$

where n is the duration (number of years) of the project.

To normalize with respect to area, the NPV is divided by the total number of hectares. Table 5 summarizes the approach for normalizing NPV with respect to year and hectares and then hectares per year. It shows that project A has a higher average annual NPV before normalization. After normalization with respect to duration and area, however, project B has the higher NPV.

Box 8 continues on next page

Box 8 continued

TABLE 5. **Normalization of two project options per year and hectare**

	NPV	Normalized NPV (NPV per year)	Normalized NPV (NPV/ha)	Normalized NPV (NPV/ha per year)
Investment A (2.1 ha)	967.98	223.58	460.94	106.47
computation		$a = 967.98 \frac{(0.05)(1.05)^5}{(1.05^5-1)}$	$\frac{967.98}{2.1}$	$\frac{223.58}{2.1}$
Investment B (0.2 ha)	175.75	30.37	878.73	151.86
computation		$a = 175.75 \frac{(0.05)(1.05)^7}{(1.05^7-1)}$	$\frac{175.75}{0,2}$	$\frac{30.37}{0,2}$

3.4 CHOOSING THE DISCOUNT RATE

A key concern in the use of discounting is the value assigned to the discount rate. There are no purely economic guidelines for choosing a discount rate, but analysts should be aware that different rates can significantly affect the present value of a future cost or benefit. In deciding on the discount rate, it is also important to consider the “responsibility to future generations [as] a matter of ethics, best guesses about the well-being of those in future, and preserving life opportunities” (TEEB, 2010a).

Government agencies may be able to provide guidance on the discount rate to be applied. For example, the General Economics Division of Bangladesh’s Planning Commission advises Bangladeshi ministries and governmental bodies to use a discount rate of 15 percent when preparing development project proposals (General Economic Division, 2014). This is in line with the Asian Development Bank (2013), which, for public projects, indicates rates in the range of 8–15 percent for developing countries and 3–7 percent for developed countries. The Philippines and India use a discount rate of 12 percent and Pakistan uses a rate of 15 percent (Asian Development Bank, 2013). The Asian Development Bank itself usually adopts a discount rate of 10–12 percent for the assessment of projects. It also uses 9 percent as the minimum economic IRR value for accepting a project in all sectors (including agriculture). A discount rate of 6 percent is allowed, however, in the case of projects with a strong social dimension, certain poverty-targeting projects (e.g. rural electrification), and projects that primarily generate environmental benefits (e.g. ecosystem protection, flood control, control of deforestation, and disaster risk management) (Asian Development Bank, 2017).

For private projects, the discount rate can be determined based on the interest rates available for alternative investment options such as those offered by a country’s central bank or state bonds. Such rates might be added to (e.g. by 1–3 percent) to account for risks associated with a certain project, given that central bank interest rates and state bond yields could be considered to be risk-free.

3.5 SENSITIVITY ANALYSIS: DEALING WITH UNCERTAINTY

Many of the parameters used in CBA, such as anticipated costs and benefits, are often not known with certainty. Future prices or quantities are estimated based on assumptions about, for example, the growth of populations and income.

Uncertainty about future costs and benefits is usually dealt with in CBA through sensitivity analysis, which tests the impacts on performance indicators of changes in selected project variables. Sensitivity analysis can be used to assess:

- project resilience to shocks, thus measuring the robustness of a project; and
- the impact of fluctuations in certain variables (e.g. increases in costs, delays in implementation, and discount rate) on project performance, thus identifying those variables that need close monitoring (IFAD, 2014).

Sensitivity analysis can also help identify the values at which crucial variables would make a project uneconomic (e.g. NPV < 0). In this kind of analysis, commonly referred to as "switching value analysis", variables are changed one by one and the impacts on indicators observed. A "scenario analysis" is needed to test a project option under conditions in which several variables change simultaneously. Three or four scenarios are created in this kind of analysis, each characterized by certain changes in key variables.

Box 9 provides an example of a sensitivity analysis applied to the two project options used in the example presented in Box 5, in which costs increase by 2 percent, 5 percent and 10 percent and benefits decrease by 2 percent, 5 percent and 10 percent.

BOX 9

Sensitivity analysis

The following spreadsheet presents a sensitivity analysis applied to project options A and B (as described in Box 5). It shows that:

- both projects are more sensitive to changes in benefits than costs (higher relative variation);
- project B is more sensitive than project A because the same relative variations in costs and benefits produce higher variations in performance indicators; and
- a 10 percent increase in costs or decrease in benefits makes both projects unprofitable (NPV < 0, B/C < 1 and a payback period of more than six years).

	Project A						
	BAU	Costs			Benefits		
		+2%	+5%	+10%	-2%	-5%	-10%
NPV	16	13	8	-1	13	7	-2
IRR	11%	10%	8%	5%	10%	8%	4%
B/C	1.09	1.07	1.04	0.99	1.07	1.04	0.99
Payback p.	6 years	6 years	6 years	>6 years	6 years	6 years	>6 years
% variation with reference to BAU							
NPV		-19%	-51%	-105%	-21%	-56%	-115%
IRR		-12%	-29%	-56%	-12%	-30%	-62%
B/C		-2%	-5%	-9%	-2%	-5%	-10%

	Project B						
	BAU	Costs			Benefits		
		+2%	+5%	+10%	-2%	-5%	-10%
NPV	13	10	5	-4	10	4	-5
IRR	9%	8%	6%	4%	8%	6%	3%
B/C	1.08	1.06	1.03	0.98	1.06	1.02	0.97
Payback p.	6 years	6 years	6 years	>6 years	6 years	6 years	>6 years
% variation with reference to BAU							
NPV		-25%	-65%	-131%	-27%	-70%	-141%
IRR		-12%	-29%	-56%	-12%	-30%	-62%
B/C		-2%	-5%	-9%	-2%	-5%	-10%

Source: United Nations (2017); FAO (2017).

Assessing risk exposure: the payback period

In addition to sensitivity analysis, the risk associated with a given project can be assessed through the payback period, which is the time taken to recover the original investment. This indicator measures the exposure risk for investors (i.e. how long they will have to wait until a project's benefits meet the costs). Technically, the payback period is the time (e.g. number of years) needed for the cumulated discounted benefits to equalize or overcome the cumulated discounted costs. The payback period does not strictly indicate how convenient an investment might be; rather, it is a measure of the length of time over which investors will need to bear the risk of an investment. A shorter payback period is desirable because it implies lower risk; thus, project options with the shortest payback periods should be preferred.

Box 10 provides an example of the calculation of a payback period based on the cashflows of the two project options used in previous examples (and introduced in Box 5).

In financial and economic analyses, reference can also be made to the break-even point. The payback period is the period needed to pay back an initial investment; the break-even point, on the other hand, identifies the point (e.g. the price or the quantity of a given good or service) at which total costs and total revenues are equal (i.e. there is no net loss or gain). For example, the break-even price of carbon stored in a forestry project would be the minimum market carbon price compensating for the foregone chance of development (e.g. conversion of the forest to another land use).

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BOX 10

Payback period

The payback period needs to be computed for the two project options, A and B (as presented in Box 5 and other subsequent boxes), to determine which is less risky. Based on the discounted cashflows for the two projects (at a discount rate , in the example, of 5 percent), the payback period can be determined for each by calculating the cumulated discounted net cashflow – that is, the difference between the cumulated discounted benefits and the cumulated discounted costs. The payback period corresponds with the project year in which the cumulated discounted net cashflow becomes positive; the project with the shorter payback period should be preferred.

In this case, the following spreadsheet shows that both project options would have a six-year payback period; thus, the cumulated discounted net cashflow would become positive at year 5.

r	5%

Project A: cash flow

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	30	-30
2	50	30	20
3	50	30	20
4	50	30	20
5	75	20	55
Total	*225*	*190*	*35*

Project B: cash flow

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	30	-30
2	0	30	-30
3	75	30	45
4	75	30	45
5	75	20	55
Total	*225*	*190*	*35*

Project A: discounted cash flow (r = 5%)

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	29	-29
2	45	27	18
3	43	26	17
4	41	25	16
5	59	16	43
Total	*188*	*172*	*NPV = 16*

IRR	*11%*
B/C	*1.09*

Project B: discounted cash flow (r = 5%)

Year	Benefits (B)	Costs (K)	Net cash-flow (B – K)
0	0	50	-50
1	0	29	-29
2	0	27	-27
3	65	26	39
4	62	25	37
5	59	16	43
Total	*185*	*172*	*NPV = 13*

IRR	*9%*
B/C	*1.08*

Project A

Year	Cumulated Benefits (ΣB)	Cumulated Costs (ΣK)	Cumulated Net cash-flow (Σ(B – K))
0	0	50	-50
1	0	79	-79
2	45	106	-61
3	88	132	-44
4	129	157	-28
5	188	173	15

Project B

Year	Cumulated Benefits (ΣB)	Cumulated Costs (ΣK)	Cumulated Net cash-flow (Σ(B – K))
0	0	50	-50
1	0	79	-79
2	0	106	-106
3	65	132	-67
4	127	157	-30
5	186	173	13

3.6 TOOLS AND RESOURCES FOR COST–BENEFIT ANALYSIS

The exercises on CBA in this manual use a spreadsheet-based software; Annex 4 contains details of this tool.

Other tools for CBA include the following:

- **RuralInvest**[17] is a free, multilingual methodology and toolkit for the preparation of sustainable agricultural and rural investment projects and business plans. A basic introductory e-learning course, and preparatory materials, are available on the FAO website.
- **WinDASI**[18] is an upgraded version of Project Data and Simulation (DASI), a software developed by FAO in the 1980s. WinDASI allows financial and economic analyses of agricultural investment projects.
- **FORVAL**[19] (FORest VALuation) is a free software package for agricultural and natural resource investment analysis developed by Mississippi State University. It is available for use online.
- The **Cost-Benefit Framework for Analyzing Forest Landscape Restoration Decisions**[20] was developed by the International Union for Conservation of Nature.
- The **Fiscal Financial and Economic Analysis** module,[21] developed by FAO, includes a **practical evaluation guide** with specific information and guidelines on performing CBA.
- An introduction to **financial economic analysis**,[22] including links to additional online resources, is available on FAO's **Investment Learning Platform**.
- The International Fund for Agricultural Development has published **Guidelines for Economic and Financial Analysis of Rural Investment Projects**[23] as well as **case studies**.[24]
- The Asian Development Bank has published the **Practical Guide for Cost-Benefit Analysis for Development**,[25] **Guidelines for the Economic Analysis of Projects**[26] and other useful documents.

[17] www.fao.org/support-to-investment/knowledge-resources/learning-tools/ruralinvest

[18] www.fao.org/tc/policy-support/list-of-publications/pub-det-tcas/en/c/46836/. An up-to-date version of the software and supporting documents, including case studies and exercises, are available via the EASYPol repository (www.fao.org/tc/easypol).

[19] http://fwrc.msstate.edu/forval/

[20] https://portals.iucn.org/library/sites/library/files/documents/2015-018.pdf

[21] www.fao.org/in-action/herramienta-administracion-tierras/module-5/practical-evaluation-guide/introduction-cba/en/

[22] www.fao.org/investment-learning-platform/themes-and-tasks/financial-economic-analysis/en/

[23] www.ifad.org/documents/10180/a53a6800-7fab-4661-ac78-faefcb7f00f8

[24] www.fao.org/documents/card/en/c/fb8ac8f6-64e1-4255-af2c-2de801220737/

[25] www.adb.org/documents/cost-benefit-analysis-development-practical-guide

[26] www.adb.org/documents/guidelines-economic-analysis-projects

- Examples of CBA in the context of Bangladesh include the **Cost-Benefit Analysis of Adaptation Strategy in Bangladesh**[27] by the Copenhagen Consensus Center and BRAC, and **The Long Road to Resilience: Impact and Cost-benefit Analysis of Community-based Disaster Risk Reduction in Bangladesh**[28] by the International Federation of Red Cross and Red Crescent Societies.
- The **Ex-Ante Carbon-balance Tool (EX-ACT)**[29] is an appraisal system developed by FAO for estimating the impact of agricultural and forestry development projects, programmes and policies on the carbon balance (defined as the net balance of all greenhouse gases expressed in carbon dioxide equivalent emitted or sequestered due to project implementation compared with a BAU scenario). EX-ACT can be applied to a wide range of development projects in the agriculture, forestry and other land-use sectors, such as those addressing climate-change mitigation, sustainable land management, watershed development, production intensification, food security, livestock, forest management and land-use change.

Module 7 refers to other ES assessment tools.

Reflection point

For group discussion:

- What are the anticipated effects of using high discount rates?
- What are the pros and cons of using high discount rates?
- What would be an appropriate discount rate for assessing the impacts of a project on ESs?

[27] www.copenhagenconsensus.com/sites/default/files/golub_climate_change_adaptation.pdf
[28] www.ifrc.org/Global/Publications/disasters/reducing_risks/Long-road-to-resilience.pdf
[29] www.fao.org/tc/exact/ex-act-home/en/

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Module 4 | Methods for valuing ecosystem services

KEY MESSAGES

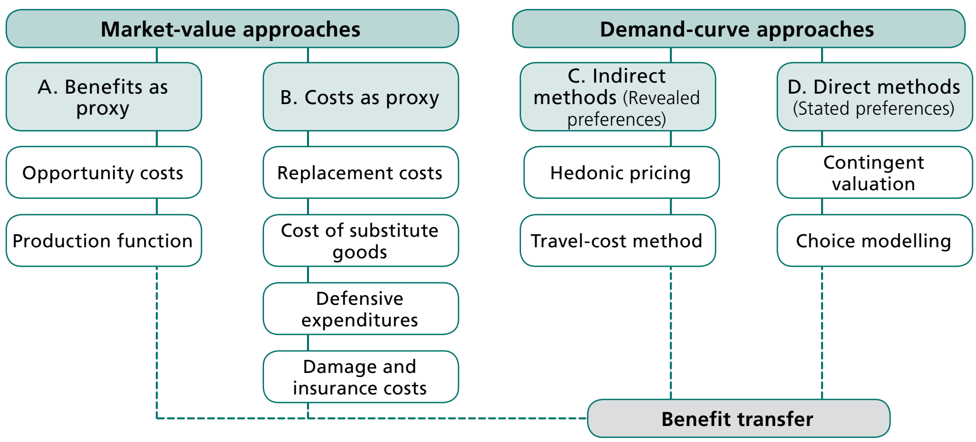
- Broadly, ESs can be valued using two kinds of method:
  1. those based on market-value analysis; and
  2. demand-curve approaches, broadly distinguishable into indirect and direct approaches.
- The estimated value of ESs for a given site (e.g. a forest area) can be applied to other sites using appropriate benefit-transfer procedures.
- Challenges in the valuation of ESs include interdependency and trade-offs among ESs; determining appropriate spatial and temporal scales; critical ecosystem thresholds; cumulative effects (for example, multiple small-scale land-use changes can have a large impact on ecosystem continuity and conservation); and ethical aspects of valuation, such as the risks associated with commoditizing natural resources.

Module 3 provides an overview of the main methods for valuing ESs, which generally fall into two broad categories (Figure 15):

1. market value (section 4.1); and
2. demand curve (section 4.2).

The advantages and limitations of these approaches are discussed below.[30]

FIGURE 15
Overview of the main methods for valuing non-priced goods



[30] A useful overview of valuation methods, including tips on implementation and examples, is available at www.ecosystemvaluation.org. See the databases listed in section 4.3 for additional examples and studies on ES valuation.

4.1 MARKET-VALUE APPROACHES

Market-value approaches rely on existing market values that can be directly or indirectly linked to non-priced goods, including ESs, and hence used to value them. A key advantage of market-value approaches is that they use data from actual markets and thus reflect the actual preferences of or costs to individuals. Another important advantage is that they are relatively easy to understand.

Market-value approaches for valuing ESs may use benefits as proxies or rely on costs and expenditures. Estimates based on market transactions reflect direct- and indirect-use values but do not capture passive-use values.

Whenever it is possible to use (reliable) market values it is highly recommended to do so, both as a (quicker) way of valuing ESs and for counter-checking values computed via different methods.

In some cases, market prices can be used for direct estimates of ESs that are actually traded, such as timber and non-timber forest products (market-price-based approach). Even where market prices are available, however, adjustments may be needed to take into account distortions such as subsidies and other factors (e.g. a market may not be fully competitive). The increasing interest in ESs and the emergence of market-based instruments for their valorization and conservation has encouraged initiatives for marketing ESs and made a larger number of values and market prices available.[31]

Methods using benefits as proxies

Methods that use benefits as proxies estimate the value of a good or service based on the financial revenues or economic benefits they generate. Such methods comprise:

- opportunity cost; and
- production function approach.

Opportunity cost

Opportunity cost, usually expressed as the difference in the NPVs of various options, is the cost of a benefit that could have been received but which has been given up to pursue a certain course of action. To maintain tree cover, for example, a farmer gives up a certain area of land that could be used for agricultural production. The foregone value of the agricultural production on the land occupied by trees represents the opportunity cost of maintaining trees on the farmer's land. Opportunity cost can be used to estimate the value of trees on farms (in the absence of a market value for them) and to quantify the amount that farmers should be paid in compensation if they are required to retain their trees (e.g. for biodiversity conservation or carbon sequestration).[32] There will also be an opportunity cost associated with protecting a wetland to conserve biodiversity rather than extracting water for irrigation on nearby farmlands.

31 Forest Trends reports on the state of markets for ESs – carbon, water-based ESs and biodiversity – are available at www.ecosystemmarketplace.com

32 For example, a recent study (Ickowitz, Sills and De Sassi, 2017) estimated the opportunity costs for smallholders involved in REDD+ projects in six tropical countries.

Opportunity cost can be used, for example, to estimate the value of a wilderness (or strict conservation) by estimating the market value of the goods and services (e.g. timber, minerals and grazing) foregone (Cavatassi, 2004). Boxes 11 and 12 present two additional examples of opportunity cost associated with avoided deforestation in tropical countries. Exercise 1 explores the opportunity cost of protecting a tropical forest area from conversion to an oil-palm plantation, and Exercise 2 examines the opportunity cost of planting trees to replace agricultural crops.

BOX 11

Opportunity cost of avoided deforestation in selected tropical countries

A recent study estimated the cost of avoiding deforestation in eight tropical countries (Grieg-Gran, 2006). Building on existing literature and data and using costs and values converted to 2005 prices and a 10 percent discount rate, the study estimated the value of avoided deforestation in terms of the opportunity cost of foregone agricultural crops and livestock products that could have been produced on deforested land. The total opportunity cost for the eight countries was about USD 3 billion – and double that if once-off timber harvesting (i.e. the net returns from timber produced in the process of converting the forest to agriculture and pasture) was factored in. The total cost was adjusted to about USD 5 billion when legal, practical and market constraints on timber harvesting were realistically taken into account.

BOX 12

Opportunity cost of protecting a tropical forest area

Butry and Pattanayak (2001) estimated the cost of protecting a tropical forest area by calculating the opportunity cost of labour for logging households in the buffer zone of Ruteng Park in Manggarai, Indonesia. In establishing a conservation regime, loggers are denied access to forest resources. The study detected differences in forest-use behaviour between rich and poor households, with the former sensitive to changes in prices of forest products and the latter sensitive to wages. The study found that the implementation of conservation measures that completely banned forest use would imply an annual loss of USD 340–460 for each local logging household. If not properly compensated, these losses could have a serious impact on the implementation of conservation measures by encouraging "leakage" to nearby areas and illegal activities in the protected area itself.

Exercise 1. **Opportunity cost of protecting a forest from conversion**

The conversion of a 10 000-ha area of tropical forest to oil-palm plantations is under discussion. The plan is to convert the total area over ten years (i.e. 1 000 ha per year). The cost of avoiding forest conversion can be estimated as the opportunity cost of foregone land use (i.e. the value that would otherwise have accrued if the area had been converted to oil-palm plantations).

The unit costs (C) for establishing the oil-palm plantations are:

C1 plantation set-up costs – USD 3 800/ha; and

C2 plantation annual management costs – USD 300/ha (all years except the year in which an area is planted).

The timber produced in the forest-clearing process would have been sold. The rotation period for oil-palm plantations is 25 years, and the average yield would have been 3.9 tonnes/ha per year, beginning one year after the plantation is established (i.e. trees yield 0 tonnes of palm oil in their first year). The market price for palm oil is USD 750 per tonne, and this is assumed to remain constant over the rotation period.

The unit revenues (R) can be summarized as follows:

R1 revenues from timber (forest clearing) – USD 1 000/ha; and

R2 revenues from palm-oil sales – USD 750 per tonne.

Using these data for costs and revenues, a cashflow for years 0–25 can be developed as per the following spreadsheet:

	Years												
	0	1	2	3	4	5	6	7	8	9	10 (...)	24	Total
Costs													
C1	3800000	3800000	3800000	3800000	3800000	3800000	3800000	3800000	3800000	3800000	(...)		**38000000**
C2		300000	600000	900000	1200000	1500000	1800000	2100000	2400000	2700000	3000000 (...)	3000000	**58500000**
Total C	***3800000***	***4100000***	***4400000***	***4700000***	***5000000***	***5300000***	***5600000***	***5900000***	***6200000***	***6500000***	***3000000*** (...)	***3000000***	**96500000**
Revenues													
R1	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	(...)		**10000000**
R2		750000	1500000	2250000	3000000	3750000	4500000	5250000	6000000	6750000	7500000 (...)	7500000	**146250000**
Total R	***1000000***	***1750000***	***2500000***	***3250000***	***4000000***	***4750000***	***5500000***	***6250000***	***7000000***	***7750000***	***7500000*** (...)	***7500000***	**156250000**
R-C	***-2800000***	***-2350000***	***-1900000***	***-1450000***	***-1000000***	***-550000***	***-100000***	***350000***	***800000***	***1250000***	***4500000*** (...)	***4500000***	***59750000***

Notes: Currency = USD; annual values in years 10–24 are constant.

Adopting a 10 percent discount rate, a discounted cashflow can be developed as per the following spreadsheet:

	Years												
	0	1	2	3	4	5	6	7	8	9	10 (...)	24	Total
C1	3800000	3454545	3140496	2854996	2595451	2359501	2145001	1950001	1772728	1611571	0 (...)	0	**25684291**
C2	0	272727	495868	676183	819616	931382	1016053	1077632	1119618	1145064	1156630 (...)	304577	**17231304**
Total C	***3800000***	***3727273***	***3636364***	***3531180***	***3415067***	***3290883***	***3161054***	***3027633***	***2892346***	***2756635***	***1156630*** (...)	***304577***	**42915594**
R1	1000000	909091	826446	751315	683013	620921	564474	513158	466507	424098	0 (...)	0	**6759024**
R2	0	681818	1239669	1690458	2049040	2328455	2540133	2694080	2799044	2862659	2891575 (...)	761442	**43078259**
Total R	***1000000***	***1590909***	***2066116***	***2441773***	***2732054***	***2949376***	***3104607***	***3207238***	***3265552***	***3286757***	***2891575*** (...)	***761442***	**49837283**
R-C	***-2800000***	***-2136364***	***-1570248***	***-1089406***	***-683013***	***-341507***	***-56447***	***179605***	***373206***	***530122***	***1734945*** (...)	***456865***	***6921689***

Notes: Currency = USD; annual values in years 10–24 are constant.

The NPV is roughly USD 6.92 million (see section 3.3 for details on calculating NPV), which translates to USD 692/ha (i.e. USD 6.92 million/10 000 ha), or USD 762 549 per year. This is the cost of avoiding deforestation and conserving the forest, calculated as the opportunity cost of foregoing forest conversion to oil-palm plantations.

Exercise 2. **Opportunity cost of protecting a forest from conversion**

Within the framework of national policies to increase forest cover and diversify income sources in rural areas, farmers in northern Bangladesh are offered the opportunity to plant tree plantations to partly replace annual agricultural crops (scenario 2 in section 1.2).

The unit (per ha) costs associated with annual crops are:

- seeds – USD 100 per year;
- fertilizers – USD 400 per year;
- pesticides and herbicides – USD 75 per year; and
- labour – USD 525 per year.

The expected annual revenue from crop sales (estimated at market prices) is USD 1 450/ha.

The unit (i.e. per ha) costs associated with forest plantations are:

- planting – USD 506;
- replanting to "fill in" gaps due to seedling mortality – 30 percent of initial planting costs (i.e. USD 152);
- Maintenance – USD 90 (year 2) and USD 30 per year (years 3–5); and
- harvesting and transportation – USD 500.

The expected revenue from timber sales at year 14 is USD 3 500/ha.

The following spreadsheets show the cashflows per ha for annual crops and forest plantations:

Annual crops

	Years								
	0	1	2	3	4	5	(...)	14	Total
Costs									
Seeds	100	100	100	100	100	100	(...)	100	**1500**
Fertilizers	400	400	400	400	400	400	(...)	400	**6000**
Pesticides and herbicides	75	75	75	75	75	75	(...)	75	**1125**
Labor	525	525	525	525	525	525	(...)	525	**7875**
Total C	***1100***	***1100***	***1100***	***1100***	***1100***	***1100***	(...)	***1100***	**16500**
Revenues									
Crop sales	1450	1450	1450	1450	1450	1450	(...)	1450	**21750**
Total R	***1450***	***1450***	***1450***	***1450***	***1450***	***1450***	(...)	***1450***	**21750**
R-C	***350***	***350***	***350***	***350***	***350***	***350***	(...)	***350***	***5250***

Notes: Currency = USD; area = 1 ha; annual values for year 5–14 are constant.

Forest plantations

	Years								
	0	1	2	3	4	5	(...)	14	Total
Costs									
Planting	506						(...)		**506**
Additional planting		152					(...)		**152**
Maintenance			90	30	30	30	(...)		**180**
Timber Harvesting and transportation							(...)	500	**500**
Total C	***506***	***152***	***90***	***30***	***30***	***30***	(...)	***500***	**1338**
Revenues									
Timber sales							(...)	3500	**3500**
Total R	***0***	***0***	***0***	***0***	***0***	***0***	(...)	***3500***	**3500**
R-C	***-506***	***-152***	***-90***	***-30***	***-30***	***-30***	(...)	***3000***	***2162***

Notes: Currency = USD; area = 1 ha; annual values for years 6–13 are null (i.e. no costs, no revenues).

Exercise 2 continues on next page

Exercise 2 continued

The following spreadsheets show the cashflows discounted at a rate of 8 percent:[33]

Annual crops

	Years							
	0	1	2	3	4	5 (...)	14	Total
Costs								
Seeds	100	93	86	79	74	68 (...)	34	**924**
Fertilizers	400	370	343	318	294	272 (...)	136	**3698**
Pesticides and herbicides	75	69	64	60	55	51 (...)	26	**693**
Labor	525	486	450	417	386	357 (...)	179	**4853**
Total C	***1100***	***1019***	***943***	***873***	***809***	***749*** (...)	***375***	**10169**
Revenues								
R1	1450	1343	1243	1151	1066	987 (...)	494	**13404**
Total R	***1450***	***1343***	***1243***	***1151***	***1066***	***987*** (...)	***494***	**13404**
R-C	***350***	***324***	***300***	***278***	***257***	***238*** (...)	***119***	***3235***

Notes: Currency = USD; area = 1 ha; annual values for years 5–14 are constant.

Forest plantations

	Years							
	0	1	2	3	4	5 (...)	14	Total
Costs								
Planting	506	0	0	0	0	0 (...)	0	**506**
Additional planting	0	141	0	0	0	0 (...)	0	**141**
Maintenance	0	0	77	24	22	20 (...)	0	**143**
Timber Harvesting and transportation	0	0	0	0	0	0 (...)	170	**170**
Total C	***506***	***141***	***77***	***24***	***22***	***20*** (...)	***170***	**960**
Revenues								
Timber sales	0	0	0	0	0	0 (...)	1192	**1192**
Total R	***0***	***0***	***0***	***0***	***0***	***0*** (...)	***1192***	**1192**
R-C	***-506***	***-141***	***-77***	***-24***	***-22***	***-20*** (...)	***1021***	***231***

Notes: Currency = USD; area = 1 ha; annual values for years 6–13 are null (i.e. no costs, no revenues).

Exercise 2 continues on next page

[33] A discount rate of 8 percent is commonly used for assessing investments in forest plantations.

Exercise 2 continued

Table 6 summarizes the results of the CBA.

TABLE 6. **Summary of a cost–benefit analysis for annual crops and forest plantations in northern Bangladesh**

	Net present value (NPV) (USD)			Benefit/ cost ratio	NPV/year
	8% discount rate	6% discount rate	10% discount rate		
Annual crop	3 235	3 603	2 928	1.32	378
Forest plantation	231	526	10	1.24	27

Thus, an investment in annual crops would achieve higher NPV and B/C values than an investment in forest plantations; the difference in NPV between the two options is roughly USD 350/ha per year. Encouraging farmers to convert part of their croplands to planted forests, therefore, would require annual incentives of about this amount. This might be feasible if, for example, such incentives were based on the additional ESs – such as carbon sequestration or biodiversity conservation – provided by planted forests and were made in the form of payments for the provision of ESs and thus conditional on the appropriate management of the plantations over time.

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Production function approach

This approach focuses on the relationship that may exist between a particular ES and the production of a market good. Ecosystem goods and services may be considered as inputs to the production process and their value can therefore be inferred by estimating the changes in the production of market goods that arise from an environmental change (TEEB, 2009). For example:

- Forests provide water infiltration services and increase water availability for irrigation, ultimately supporting an increase in the production of agricultural crops;
- The presence of certain pollinator species in nearby forest areas might enhance pollination, thus helping increase the production of certain agricultural crops (Box 13);
- Mangroves support offshore fisheries by serving as spawning grounds and nurseries for fry (Box 14).

BOX 13

The economic value of insect pollination in the Hindu Kush Himalayan region and Chittagong

Partap *et al.* (2012) estimated the total economic value of insect pollination for selected crops in the Hindu Kush Himalayan region[34] using the methodology developed by Gallai and Vaissière (2009). This methodology is based on the hypothesis that the economic impact of pollinators on agricultural outputs is measurable through the use of dependence ratios that quantify the impact of a lack of insect pollinators on crop production value. The approach also looks at the vulnerability of different crop categories to pollinator decline.

The study found that the total economic value of the pollination service in the study area was equivalent to nearly USD 2.7 billion per year. In the Chittagong Hill Tracts (Bandarban, Rangamati and Khagrachari districts), the economic contribution of pollination was evaluated for 42 major crops – ten fruits, five oilseeds, five pulses, two spices, two tree nuts and 18 vegetables. The total economic value of insect pollination was estimated as USD 53.8 million per year, with a vulnerability ratio of 22.7 percent (which means that a total loss of the pollinator population would reduce the total production value of the selected crops by 22.7 percent).

[34] This includes: the Chittagong Hill Tracts in Bangladesh; Bhutan; the Chinese Himalayan provinces; Himachal Pradesh and Kashmir in the northwestern Indian Himalayas; Uttarakhand in the central Indian Himalayas; and the Himalayan region of Pakistan.

BOX 14

Production function: the role of wetlands and mangroves in supporting offshore fisheries

Barbier (2000) applied the production function approach to assess the role of wetlands, including mangrove forests, in supporting offshore fisheries by serving as spawning grounds and fry nurseries. The size of wetland areas along the coast (S) might have an influence on the marketed output of an economic activity (Q), in this case represented by the catch of wetland-dependent species. This influence can be summarized in the following general production function:

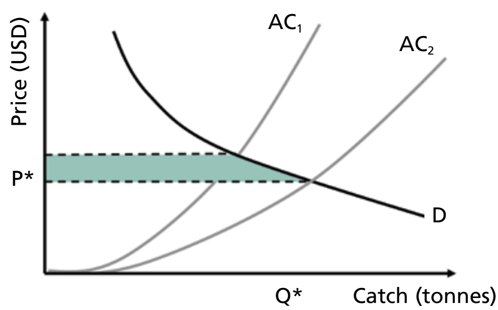
$$Q = f\,(X_i \ldots X_k, S)$$

where $X_i \ldots X_k$ are the standard inputs of a commercial fishery, independent of S.

When Q is measurable and either there is a market price for it or one can be imputed, determining the marginal value of the resource is straightforward. Lynne, Conroy and Prochaska (1981), for example, found that an increase in wetland area increases the abundance of wetland-dependent species and thus lowers the cost of the catch (assuming that fish stocks are constant – that is, that the harvesting of fish always offsets any natural growth in fish stock). The value of the supporting service provided by wetlands to fisheries can be estimated as the sum of the resultant changes in surpluses for consumers (Figure 16) and producers.

FIGURE 16

The consumer surplus derived from changes in the average cost of fish harvesting based on changes in coastal wetland areas



Notes: AC = average cost; D = demand; P = price.
Source: Modified from Barbier (2000).

Box 14 continues on next page

Box 14 continued

Anneboina and Kavi Kumar (2017) analysed the role of Indian mangrove forests in marine fish output (or harvesting): although not directly influencing fish production, mangroves can affect the technical efficiency of fish production by providing an enabling environment for the growth of fish stocks, which in turn can influence fish production.

Using a two-step methodological approach, they estimated the production function[35] and derived the technical efficiency values for fish production; and estimated technical efficiency values by regressing them for a mangrove area and other control variables to ascertain the influence of mangroves on technical efficiency.

The mean value for technical efficiency in the sample was 45 percent. Thus, on average, the marine fish output could be improved by 55 percent without any additional resources through the more efficient use of existing inputs and technology. The study also found that mangroves improve the efficiency of fish production; specifically, a 1-km^2 increase in mangrove area leads to an increase in total marine fish production of roughly 186 tonnes per year (i.e. the annual contribution of mangroves to total marine fish production is 1.86 tonnes/ha). Given India's total mangrove forest area of 4.66 million ha, this would correspond to a total annual production of around 8.67 million tonnes; thus, mangroves contribute 23 percent of India's total national fish production at a total value of USD 1.13 billion.[36] The estimated contribution of mangroves to India's annual fish production of 23 percent is in line with estimates collected by Anneboina and Kavi Kumar (2017) from across the world, in which the contributions of mangrove forests are estimated in the range of 10–32 percent.

Because agricultural crops and fish resources have well-known prices, an increase in production can easily be quantified in monetary terms and the additional value produced can be linked to the support provided by ESs. The assumption behind this approach is that the relationship between ESs and valued end points (final products or outcomes) is known. The main problem and potential limitation of this approach is that adequate data on, and understanding of, the cause–effect linkages between the ESs being valued and the marketed commodities are often lacking (Daily *et al.*, 2000). In other words, the production functions of ESs are sometimes not sufficiently well understood to quantify how much of a service is produced or how changes in ecosystem condition or function will translate into changes in the ESs delivered (Daily, 1997). Moreover, the interdependencies of ESs may increase the likelihood of double counting (Barbier, 1994; Costanza and Folke, 1997).

The production function approach is applicable to regulating and supporting services.

35 The production function used by Anneboina and Kavi Kumar (2017) is:
$ln\,(Q_{it}) = \beta_0 + \beta_1\, ln(x_{1it}) + \beta_2\, ln\,(x_{2it}) + v_{it} + u_{it}$
Where β_is are the parameters to be estimated and x_1 and x_2 are the two inputs (i.e. fisheries outlay and fishing vessels, respectively). Q is marine fish output (production), and i and t refer to the coastal state and the year in question, respectively. v_{it} is an error variable capturing the effect of the other omitted variables that may influence output, and u_{it} is the inefficiency term reducing the output.

36 Assuming that the total value of marine fisheries in India is about USD 4.92 billion (Kavi Kumar *et al.*, 2016)

Methods adopting costs as a proxy

The aim of methods adopting costs as a proxy (also called cost-based methods) is to estimate the value of a good or service based on the costs associated with them, such as the costs needed to produce (or reproduce) a certain good or service or to substitute it with a similar or equivalent one. Methods in this category include (see Figure 15):

- replacement cost;
- cost of substitute goods;
- defensive expenditures; and
- damage and insurance costs.

Replacement cost

Replacement cost refers to the cost of replacing or restoring a damaged asset to its original state as a measure of the benefit of restoration. Examples include the replacement of a forest area damaged or destroyed by natural hazards (e.g. storms or fires) or the replacement of soils or nutrients lost through erosion due to deforestation. Replacement cost can also be interpreted as **production cost** – that is, the cost of producing (or reproducing) a certain asset, independent of the fact that it has been damaged. For example, the value of a newly afforested area might be estimated based on the cost of creating it (i.e. the cost of planting, tending, etc.).

Box 15 and Exercise 3 provide simple examples of the replacement-cost method. Module 6 refers to the application of this method (as production cost) in presenting examples of coastal protection against storms and tidal surges.

BOX 15

Replacement cost: an example

A forest is damaged by a natural event (e.g. a storm). The value of the forest (V) can be estimated using the replacement-cost (or production-cost) method by estimating the costs that would have to be borne to reproduce the forest, according to the following formula:

$$V = \sum_{t=0}^{n} K_{i,t} \, (1 + r)^t$$

where K_i = all costs (e.g. removal of debris; ploughing and other preparatory activities; supply of seedlings; planting; and annual management costs) related to forest replacement; r = the discount rate; and n = the time horizon (e.g. number of years) to attain a size or quantity of benefits equivalent to that supplied by the damaged forest before the damage occurred (sometimes called "years to parity").

Exercise 3. **Valuing strip plantations through the replacement-cost method**

About 10 km of strip plantations have been damaged by intense windstorms. The damaged trees were 9–10 years old, and the normal rotation period for the strip plantations is 13 years.

Replacement costs comprise:

- seedlings (1 000/km) – USD 0.125 per seedling;
- planting – USD 0.045 per seedling;
- replanting to "fill in" gaps due to seedling mortality – 20 percent of originally planted seedlings need to be replaced at year 1; and
- maintenance – USD 0.038 per seedling (years 1 and 2).

It is assumed that woodfuel sales fully cover the cost of removing trees damaged by the storms; those costs, therefore, are not accounted for. The number of years to parity (*n*) is assumed to be ten.

The following spreadsheet presents a cashflow based on the costs given above:

	Years										
	0	1	2	3	4	5	6	7	8	9	**Total**
Seedlings	1250										**1250**
Planting	450										**450**
Vacancies		340									**340**
Maintenance		380	380								**760**
Total costs	***1700***	***720***	***380***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	**2800**

Notes: Currency = USD.

Based on the cashflow, the total replacement value has been calculated using the general formula presented in Box 15.

Then:

$$V = (1\ 250+450)\ (1.15)^{10}+(340+380)\ (1.15)^{9}+(380)\ (1.15)^{8}$$

$$V = 6\ 877+2\ 533+1\ 162 = USD\ 10\ 573$$

Therefore, the value of damaged strip plantations estimated through the replacement-cost method is USD 10 573 (i.e. roughly USD 1 060 per km).

The cost of substitute goods

This approach considers the cost of providing a substitute good (or surrogate) that has a similar function to a given ecosystem good or service. Examples include mangrove and coastal forests that provide protection against cyclones and tidal surges versus the cost of building human-made defences (e.g. seawalls and dykes) of equal effectiveness; fodder provided by a forest versus alternative animal feedstock; the pollination service provided by a forest versus artificial pollination (e.g. Alsop, de Lange and Veldtman, 2008); the regulating ESs provided by forests that minimize the sedimentation of downstream water reservoirs versus the cost of dredging reservoirs; and the regulating ESs provided by forests that maintain water quality (filtration) for downstream users versus the cost of constructing and keeping water-treatment plants and systems (Box 16 describes the well-known case of New York City and another example in Uganda).

A limitation of this method is the difficulty of identifying adequate substitutes. Human-built alternatives are often poor substitutes because they cannot normally ensure the same range of ESs as natural infrastructure. For these reasons, the cost-of-substitute-goods approach for valuing ESs should be used with caution, especially when there is a high degree of uncertainty (Barbier, 2016; Pascual and Muradian, 2010).

Exercise 4 provides an example of estimating the value of the soil-erosion control provided by a forest through the cost-of-substitute-goods approach.

BOX 16

Estimating the value of ecosystem services using the cost-of-substitute-goods method

The New York City water system serves 9 million people, supplying 1.2 billion gallons of water (about 4.5 billion litres) per day to about 800 000 residential and commercial buildings. Water is collected in three watersheds north of the city, covering a combined area of 830 000 ha. Various options for maintaining the quality of the city's drinking-water sources were discussed in the early 1990s, including a massive filtration programme for cleaning downstream water (e.g. through sewage and septic system upgrades), and the development of a comprehensive programme of watershed protection (later called "whole farm planning") with the aim of avoiding (or at least significantly reducing) water pollution at the source. The second option involved farmer training, the adoption of best practices, and improving farming practices (e.g. the adoption of no-tillage farming). The estimated cost of implementing the filtration programme was USD 4 billion–USD 6 billion, plus an additional USD 250 million annually in operating costs, and the estimated cost of watershed protection was USD 1.5 billion. It can be assumed that the total value of the provision of good-quality drinking water by the managed watershed equals the total cost of the filtration programme that should be implemented to clean downstream water. The difference in cost between the two options can be viewed as the net value of the ESs provided (Appleton, 2002).

Ring *et al.* (2010) reported the case of the Nakivubo Swamp, a large wetland area (with a catchment area exceeding 40 km^2) that provides water-cleaning and filtration services to the Greater Kampala Metropolitan Area, Uganda. The swamp cleans water polluted by industrial, urban and untreated sewage waste in the city area. A study analysed the cost of replacing the wetland and the wastewater-treating ESs with an artificial sewage treatment plant and the construction of latrines to process sewage from nearby slums. It concluded that the creation and management of an improved artificial system for treating wastewater would cost up to USD 2 million per year more than the management costs associated with maintaining the wetland to optimize its regulating ESs and preserve its ecological integrity.

Box 16 continues on next page

Box 16 continued

The regulating ESs that provide coastal protection and defences against natural risks are of paramount importance in Bangladesh. Price (2014) reported a study that estimated it would cost up to USD 130 billion to build seawalls and other infrastructure sufficient to protect Bangladesh from the projected effects of rising sea levels – about double Bangladesh's present gross domestic product (GDP). This amount could be compared with the protection provided by mangrove forests and other coastal forests as surrogates for (or complemented by) grey infrastructure (see module 6).

Exercise 4. **Valuing the protection provided by forests against soil erosion using the cost-of-substitute-goods method**

Deforestation and land development in hilly environments can increase erosion risk, especially in areas subject to heavy rainfall. The value of the protection against erosion provided by forests can be estimated through the cost of substitute goods. Various erosion-control measures can be used as substitutes, depending on the slope and type of erosion. Grassing and terracing can be effective solutions on moderate slopes (up to 5 percent) and for gully erosion.

Consider a 300-ha area subject to erosion risk. Of the total area, 200 ha needs a moderate level of protection and can therefore be protected through grassing. The remaining 100 ha requires a moderate-to-high degree of protection, and cut terraces and fascines (bundles of brushwood used to strengthen earthen structures) made of local species are needed.

The costs (and other features) associated with the implementation of these erosion-control measures are:

- grassing – USD 0.50/m^2 (with an operational lifespan of eight years). This amounts to USD 0.50/m2 x 10 000 m^2 = USD 5 000/ha;
- Cut terraces with fascines (15 fascines/m at a spacing of approximately 10 m for a development of approximately 1 000 m/ha) – USD 12.10/m (with an operational lifespan of 15 years). This amounts to USD 12.10/m x 10 000 m/ha = USD 12 100/ha.

The annual maintenance costs are estimated at 10 percent of implementation costs (i.e. USD 500/ha for grassing and USD 1 210/ha for cut terraces).

The following spreadsheet presents a cashflow based on the costs given above:

	Years										
	0	1	2	3	4	5	6	7	8 (...)	14	Total
Grassing (implementation)	1000000								(...)		**1000000**
Cut terraces (implement.)	1210000								(...)		**1210000**
Maintenance grassing	100000	100000	100000	100000	100000	100000	100000	100000	(...)		**800000**
Maintenance cut terraces	121000	121000	121000	121000	121000	121000	121000	121000	121000 (...)	121000	**1815000**
Total costs	***2431000***	***221000***	***221000***	***221000***	***221000***	***221000***	***221000***	***221000***	***121000*** (...)	***121000***	**4825000**

Notes: Currency = USD; annual values are constant for years 8–14.

Exercise 4 continues on next page

Exercise 4 continued

For each erosion-control measure, the implementation (year 0) and maintenance costs per ha were used to calculate annual costs (A_k) per unit area according to the following formula:

$$A_k = \frac{(K \times r)}{(1+r)^t} + M$$

where K = the implementation cost of each erosion-control measure (i.e. USD 5 000/ha for grassing and USD 12 100/ha for cut terraces); r = the discount rate (15 percent); t = the operational lifespan of each erosion-control measure (i.e. 8 years for grassing and 12 years for cut terraces); and M = the annual maintenance cost of each erosion-control measure (i.e. USD 500/ha for grassing and USD 1 210/ha for cut terraces).

Thus, the total cost is USD 745/ha per year for grassing and USD 1 433/ha per year for cut terraces. Considering the total area over which each erosion-control measure will be applied, the total cost of substitute goods (per year) = (USD 745/ha x 200 ha) + (USD 1 433/ha x 100 ha) = USD 292 341, or USD 974.50/ha per year.

This amount can be viewed as the total annual value of the ESs provided by forests to minimize soil erosion, as estimated using the cost-of-substitute-goods method.

Defensive expenditures

Defensive expenditures include all expenditures sustained to avoid or reduce the effects of a negative externality or to reduce or compensate for damage arising from such an externality. For example, the amount spent by coastal communities to upgrade their houses and other buildings to protect against the increasing frequency and severity of cyclones and storm surges can be considered a defensive expenditure and used to estimate the protection service provided by mangroves and other coastal forests (Box 17). The defensive expenditure approach builds on observable behaviour, and data tend to be available and accessible. On the other hand, a limitation is that expenditures might be made for multiple reasons (i.e. for "joint" benefits) and not just to mitigate a single negative externality. Moreover, defensive expenditures normally represent the minimum amount that people are willing to pay to avoid or prevent environmental degradation or a certain level of damage (Abelson, 1996).

BOX 17

Defensive expenditure against storm damage in coastal areas of Bangladesh

Mahmud and Barbier (2014) analysed *ex-ante* self-protection and *ex-post* self-insurance spending by coastal households in Bangladesh affected by Cyclone Sidr in 2007 to mitigate storm-inflicted damage with a view to determining (among other things) whether the presence of mangrove forests influenced such spending. The hypothesis was that households living close to mangroves might undertake different defensive actions in response to the perceived threat of a storm compared with households without such "natural barrier" protection. Self-protection expenditure refers to actions that decrease the probability that a household will incur property damage from a storm event. Examples for coastal households in Bangladesh include converting mud-built houses to brick; raising the height of houses; moving houses inside embankments; taking refuge in neighbours' houses; and relocating away from shorelines to safer places. Self-insurance expenditure refers to investments in human, physical and social capital by households to reduce their losses in the event of storm-inflicted damage. Examples for coastal households in Bangladesh include income-source diversification; crop and plot diversification; private transfers via remittances and charities; reciprocal gift exchanges; and inter- and intra-household income transfers driven by insurance motives (or informal risk-sharing).

The study took into account households living in "protected" areas (i.e. areas located behind the Sundarbans mangrove forests) and households living in "non-protected" areas (i.e. areas not located behind the Sundarbans mangrove forests). The average amount spent per household on self-protection was USD 1 825 in protected areas and USD 768 in non-protected areas. The presence of a natural barrier may encourage households to invest more in self-protection to reduce even further the risks of storm damage to their home and other property. On the other hand they might spend less on self-insurance for damage inflicted by a storm because they feel more protected.

Damage and insurance costs

Damage and insurance costs comprise the expenditure that would be (or has been) borne if damage occurs due, for example, to natural disasters such as flooding or landslides and the expenditure on insurance payouts for events and other negative externalities such as storms (Box 18) and adverse weather conditions. Like the other "costs as proxy" approaches described above, the damage and insurance costs method is mainly used for valuing regulating ESs. The rationale behind it is that the provision of certain regulating ESs can reduce damage due to a given natural disaster, thus reducing the costs associated with them. In addition, people who perceive that they are protected by, for example, a coastal forest, are likely to spend less on self-insurance for damage inflicted by natural hazards/events (e.g. storms).

BOX 18

Insurance costs for storm damage in coastal areas of Bangladesh

In the study reported in Box 17, Mahmud and Barbier (2014) found that the average expenditure on self-insurance per household was USD 93 in the protected area and USD 407 in the non-protected area. When households know they are better protected by a nearby mangrove forest they tend to spend less on self-insurance for damage inflicted by storms. On the other hand, the presence of a natural barrier may encourage households to invest more in self-protection to reduce even further the risks of storm damage to their homes and other property.

Concluding remarks on methods using costs as proxies

In general, costs-as-proxy methods are less data- and resource-demanding than other methods and approaches (e.g. demand-curve approaches). They are useful in providing rough estimates of the economic values of ESs, but they are subject to other constraints (e.g. the degree of similarity or substitutability, in the case of the substitute goods approach). Some authors argue that costs are usually not an accurate measure of benefits (Barbier, 2016). Moreover, these methods do not consider social preferences for ESs, or the behaviour of individuals in their absence. The underlying assumption, which may not always be valid, is that the benefits are at least as great as the costs involved in replacing or restoring an ES. If society is not prepared to pay for human-made repairs or substitutes (e.g. if there is insufficient demand), replacement-cost and cost-of-substitute-goods methods will tend to overestimate the value of ESs. Alternatively, if society is prepared to pay for the human-made repairs or substitutes, the cost of replacement provides only a lower-bound estimate of the benefit (i.e. we only know that the benefits of restoration exceed the costs) (Brouwer *et al*., 2013). The fact that an ecosystem is destroyed or otherwise altered and the related ESs are reduced does not mean that people will demand or be willing to pay for alternatives (Anon, 2017). Therefore, costs-as-proxy methods should only be used when other approaches are infeasible or time or budgetary constraints do not allow their use.

4.2 DEMAND-CURVE APPROACHES

Demand-curve approaches can be used for valuing ESs when market values are unavailable. Demand-curve approaches build on the demand curve (Box 19) of a certain good or service and refer to existing markets for goods or services linked to ESs or which simulate markets for them.

BOX 19

Demand curve

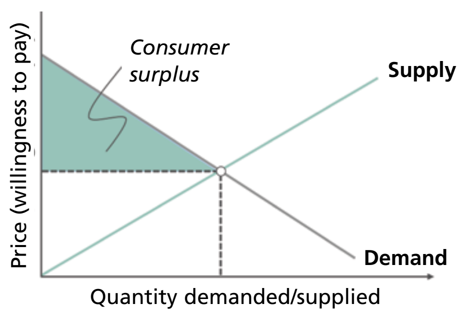
Demand curves graphically represent demand functions – that is, the relationship between the price of a certain good or service and the amount of it that consumers are willing and able to purchase at a given price. For goods or services without markets (and hence no price), such as many ESs, the curve represents consumers' willingness to pay (WTP) rather than the market price.

The market price of a good or service does not necessarily measure its economic value. Because individuals vary in their preferences, differences exist in the amount each is willing to pay for a product. In other words, the market price is the *minimum* amount that people who buy a certain good or service are willing to pay for it. When people purchase a marketed product, they compare the amount they would be willing to pay with the market price; they only purchase it if their WTP is equal to or greater than the price. If an individual buys a product for a price below his or her own valuation of it, that consumer is said to have derived *consumer surplus* from the purchase. This is represented graphically by the area under the demand curve for a product above its price (i.e. the shaded triangular area in Figure 17).

For products with no explicit market price, markets need to be simulated to derive the demand curve and consumer surplus.

FIGURE 17

Demand curve and consumer surplus



Use values can be estimated by direct methods (revealed preferences) and by contingent valuation. Passive-use values can be estimated using contingent valuation and voluntary donations.

Direct methods

Direct methods are also known as "revealed preferences" because they use data on the observed preferences and actual behaviour of individuals to derive values. In determining the value of ESs, revealed-preferences methods build on the links between marketed goods and ESs based on the influence on demand for a marketed good of the quality or quantity of an ES (TEEB, 2009). The two main methods in this category are **travel cost** and **hedonic pricing**.

Travel cost

The travel-cost method is used to estimate the direct-use value of cultural ESs, especially tourism- and recreation-related values. The rationale for this method is that tourism and recreational experiences have costs for visitors, including the direct expense involved in travel (i.e. travel costs) and the cost of entering a site (entrance fees), as well as the opportunity cost of their time. The willingness to pay (WTP) to visit a site can be estimated based on the number of trips that tourists make and their associated travel costs. There are various approaches to estimating values using travel costs, including the individual travel-cost method and the zonal travel-cost method:

- The *individual travel-cost method* focuses on single visitors. In this case, the number of trips is a function of the travel costs and socio-economic features associated with each visitor: i.e. $t_i = f(K_i, X_i)$, where t_i = number of trips for visitor i; K_i = travel costs for visitor i; and X_i = socio-economic features of visitor i.
- The *zonal travel-cost method* uses zones – usually an array of concentric circles – that indicate the distance from a study site. Each zone is defined in terms of the travel costs needed to get to the site. The visit rate for each zone is estimated using data on zone population sizes (e.g. number of trips per 1 000 inhabitants): i.e, $t_j / P_j = f(K_j, X_j)$ where t_j = number of trips for visitor coming from zone j; P_j = the population living within zone j; K_j = travel costs from zone j; and X_j = socio-economic features of visitors coming from zone j.

Using regression analysis it is possible to identify the equation that relates visits per capita to travel costs and other important variables. Usually this is done by estimating variations in the number of visitors in light of differing hypothetical entrance fees (Box 20, Exercise 5). The entrance fee can be set according to various objectives (e.g. to maximize revenues for a site; Exercise 6).

A third approach using the travel-cost method, "random utility", is substantially different from the other two. It estimates the probability of choosing a certain site over all other available sites depending on the characteristics of all sites and the travel costs involved. This approach is highly data-intensive and uses complex econometric models.

BOX 20

The zonal travel-cost method

Table 7 presents visitation data for a certain site collected through a field survey of visitors travelling from one of five zones.

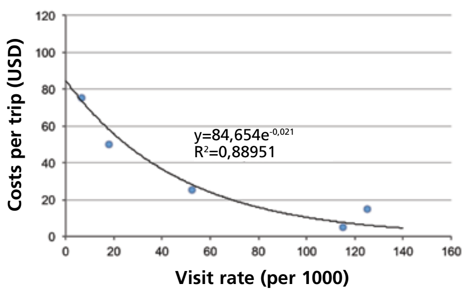
TABLE 7. **Visitation data for visitors to a certain site travelling from one of five zones, A–E**

(a) Zone	(b) Distance (km)	(c) Population	(d) No. trips per year	(e) Visitation rate (*c* x *d* x 1 000)	Average cost per trip (USD)	Total costs (*d* x *f*) (USD)
A	0–100	10 000	1 152	115.2	5	5 760
B	101–200	120 000	15 000	125.0	15	225 000
C	201–300	150 000	7 850	52.3	25	196 250
D	301–400	50 000	900	18.0	50	45 000
E	401–500	100 000	650	6.5	75	48 750

By plotting the average costs per trip and the visitation rate, it is possible to identify a regression function and curve that best fits the data, thereby showing the relationship between cost per trip and visitation rate (Figure 18). This function can be used to determine how the visitation rate changes as the cost per trip increases (e.g. due to the introduction of an entrance fee to the site). The cost is increased incrementally (e.g. by increasing baseline travel costs by units of USD 0.5) until the visitation rate becomes null – that is, until the cost of visiting a site becomes so high that people will no longer be willing to pay. A demand curve representing the demand for recreation for the site under study can be obtained by plotting the additional costs for all zones and the corresponding total number of visits. The area under the demand curve represents the recreational value of the site and can be calculated by integrating the corresponding function (Figure 19). In this case, the total recreational value would correspond to about USD 1.28 million.

FIGURE 18

The relationship between cost per trip and visitation rate, in a hypothetical example

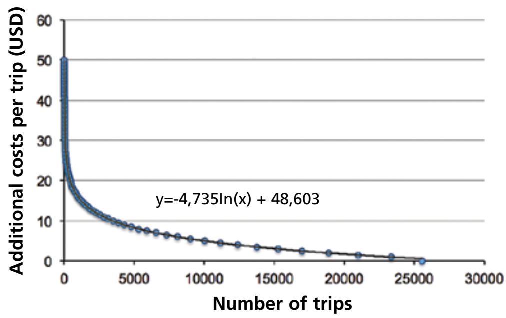


Box 20 continues on next page

Box 20 continued

FIGURE 19

Additional cost per visit versus number of trips, in a hypothetical example



Although the zonal travel-cost method is used widely and has certain advantages (e.g. it is based on observations of people's actual behaviour, it is relatively inexpensive, and interpreting results is straightforward), it has limitations. For example, it only allows users to obtain direct-use values and does not consider those people who do not visit a site but still value it (i.e. a site's existence value). The method requires considerable data (and effort to collect them). It assumes that individuals take trips for single purposes or to single destinations; it is difficult to apportion travel costs if multiple purposes or destinations apply, and there is a risk, therefore, of overvaluing a site.[37] Problems may also arise in measuring the value of time spent travelling to the site through the opportunity cost of time. There remains a lack of consensus on the appropriate unit value for this cost (e.g. hourly wage or a fraction of it). In some cases, the travel itself might be part of the recreational experience and should be valued accordingly. The zonal travel-cost method can be problematic when all visitors have similar travel costs, such as when most visitors live near a site (e.g. an urban park): differentiation among visitors or zones might be impossible and higher values might not be captured.

Values can also be affected by the presence of substitute sites that visitors might choose to visit instead of the one under study. For example, if visitors A and B travel the same distance to reach a site, they might be assumed to value it in the same way. Visitor A, however, lives close to a substitute site but decides to travel further to the site under study, implying a higher value, but this is not captured in the method.

[37] In the case of multiple purposes or destinations, the random utility travel-cost method can be used to determine WTP for the individual characteristics of each purpose or destination (Brown and Mendelsohn, 1984).

Exercise 5. **Travel-cost method and entrance fee to a park**

The managers of a park are considering introducing an entrance fee, for two purposes: to generate revenues (that could be reinvested in the area) and to reduce congestion during the most crowded months. Thus, the introduction of a fee could both improve the recreational experience for visitors and reduce pressure on the park.[38]

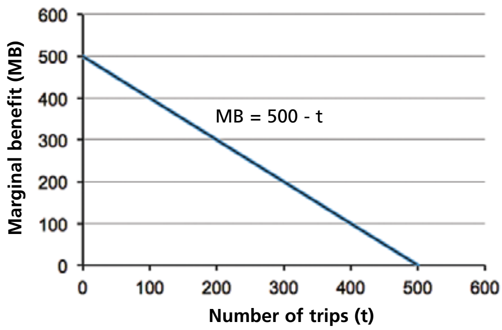
Based on data gathered through a field survey, visitors mostly come from a nearby urban area and the average travel cost (TC) is USD 50. The value each visitor obtains by visiting the park (the marginal benefit, MB) – that is, the additional amount of satisfaction that an individual obtains from an additional visit to the park – has been estimated based on the survey and is expressed by the following linear function (see also Figure 20):

$$MB = 500 - t \qquad (A1)$$

Where t is the total number of trips to the park.

The negative slope of the linear function indicates a decreasing level of enjoyment with additional visits. Thus, the more a person visits a park, the less benefit the person receives from each additional visit.

FIGURE 20
A hypothetical example of the relationship between the marginal benefit an individual receives from visiting a park and the number of trips made



In the hypothetical example, the benefit obtained from visits also decreases with park congestion; thus, the more crowded the park, the less people enjoy the visit. This can be seen as a congestion cost (CC) that visitors incur in terms of their enjoyment and that the park incurs in terms of pressure on natural resources. From survey data, it has been determined that the congestion cost (CC) can be approximated by the following linear function:

$$CC = t - 300 \qquad (A2)$$

Where t = the number of trips to the park.

Exercise 5 continues on next page

[38] This exercise is adapted from Killian (2015). For more information see https://rstudio-pubs-static.s3.amazonaws.com/72135_dc45211d976842c2a9a8c8b5f2472ff0.html

Exercise 5 continued

The total marginal social cost (MSC) (i.e. the aggregated cost of visiting the park) is given by the sum of TC and CC:

$$MSC = TC+CC \qquad (A3)$$

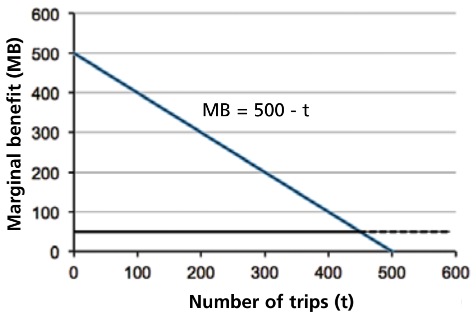
If no entrance fee is paid to access the park, we can expect that $MB = TC$. The number of trips (t), therefore, would be:

$$500 - t = 50$$

Thus, $t = 450$ *trips* (see Figure 21).

FIGURE 21

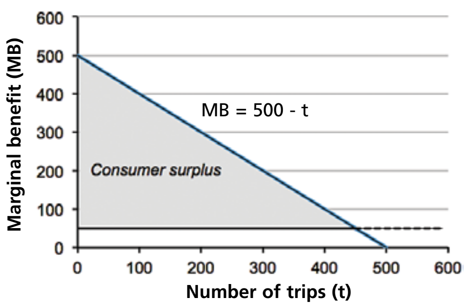
A hypothetical example of the relationship between the marginal benefit an individual receives from visiting a park and the number of trips made



The consumer surplus associated with these trips (no entrance fee) is given by the area shaded in grey in Figure 22. This corresponds to 0.5 × (450 × 450) = *USD* 101 250. If the demand function was non-linear, it would need to be integrated over t.

FIGURE 22

A hypothetical example of the relationship between the marginal benefit an individual receives from visiting a park and the number of trips made, showing the consumer surplus



Exercise 5 continues on next page

Exercise 5 continued

To set an efficient entrance fee, the MSC should be calculated:

$$MSC = TC+CC$$

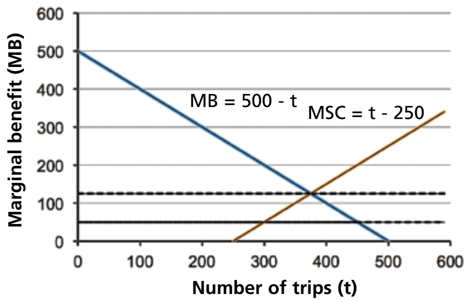
Substituting TC = USD 50 and (A2), we get:

$$MSC = 50 + t - 300$$

$$MSC = t - 250 \quad (Figure\ 23).$$

FIGURE 23

A hypothetical example of the relationship between the marginal benefit an individual receives from visiting a park and the number of trips made, showing the marginal social cost



To solve for optimal (i.e. efficient) values, MB should equal MSC:

$$MB = MSC$$

$$500 - t = t - 250$$

$$2t = 750$$

$$t = 375$$

Thus, because t = 375, and using equation (A1), we get:

$$MB = 500 - 375 = 125$$

In this example, therefore, USD 125 is the optimal cost. Because TC = USD 50:

$$Optimal\ entrance\ fee = 125 - 50 = USD\ 75$$

By imposing this fee, the number of visits would decline by 75 (compared with the case where the entrance fee is zero) to 375.

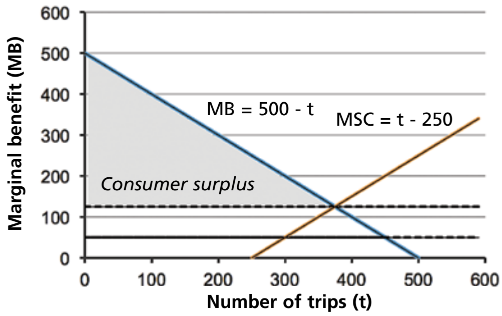
The consumer surplus would be $0.5 \times (375 \times 375) = USD\ 70\,312.50$ (Figure 24): that is, roughly 30 percent less than if the entrance fee was zero. At a fee of USD 75, revenues for the park would be $75 \times 375 = USD\ 28\,125$, which is about 40 percent of the consumer surplus.

Exercise 5 continues on next page

Exercise 5 continued

This amount could be invested to offer additional services and benefits that would justify the payment of the fee (e.g. better maintenance and conservation activities and more support staff and interpretation).

FIGURE 24
A hypothetical example of the relationship between the marginal benefit an individual receives from visiting a park and the number of trips made, showing the consumer surplus and the amount monetized by the park fee



Exercise 6. **Setting an entrance fee to maximize revenues for a recreational site (scenario 3)**

The managers of the recreational site presented in Box 20 want to set an entrance fee to maximize park revenues with a view to improving the services offered to visitors. Based on the values reported in Figure 19, this can be done by looking for the combination of additional cost (assuming this corresponds with the introduction of an entrance fee) and number of visits that maximizes revenue (i.e. maximizes the product of the additional cost and the number of trips). Figure 25 shows how revenue would change as the fee changes. Revenue would increase as the fee increases from USD 0.00 to USD 4.50 and then decrease to zero at an entrance fee of about USD 50. The highest revenue would be achieved with an entrance fee of USD 4.50, which would attract 11 136 visits (see Figure 19) and generate a total of USD 50 113.51.

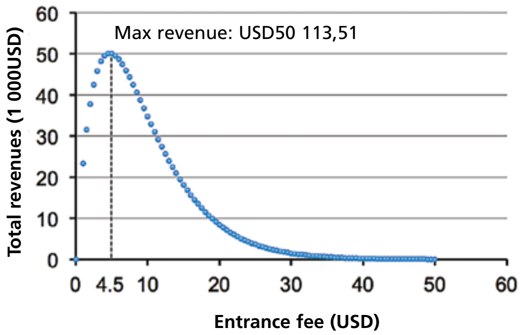
This approach could be used for the Bangabandhu Sheikh Mujib Safari Park in Gazipur (see scenario 3 in section 1.2). Given the entrance-fee structure there, a survey would be needed to determine the number of visitors associated with the various fees (e.g. adults, children, students, individuals/groups and non-nationals). This would also improve understanding of how the various visitor typologies (and associated fees) contribute to current and potential park revenues and enable the development of demand curves for each (following the approach presented in Box 20). The survey would also be an opportunity to collect general

Exercise 6 continues on next page

Exercise 6 continued

information on visitors, such as age; education level; income; the kinds of activity they typically engage in at the park; satisfaction with the services offered at the site; and their needs or expectations in terms of additional services. The WTP for additional services could also be assessed to support decision making on fees that would allow the park to obtain a given number of visitors and an increase in park revenues of 50 percent, as required in scenario 3.

FIGURE 25
Change in total revenue with increasing park entrance fee, in a hypothetical example



Hedonic pricing

Other features being equal, houses located near parks or areas with desirable amenities are often more expensive than properties further away. In other words, characteristics such as a nice view, easy access to green areas, peacefulness and good air quality affect property values. Conversely, properties near polluted or noisy sites tend to be lower-priced than equivalent properties without those negative aspects. Price differences, therefore, may be attributable to ESs, such as scenic beauty.

The hedonic-pricing approach infers demand for environmental attributes such as scenic or air quality based on differences in the price of marketed commodities such as houses. This approach assumes that the price of a good reflects its characteristics, including certain environmental attributes. Changes in the quality of such attributes, therefore, influence the price of the marketed commodity. A common application of the hedonic approach is the analysis of house-price variations in relation to environmental characteristics (Freeman III, 1979) such as landscape amenity, proximity to a forest or green area, and air quality.

Statistical analyses (e.g. regression analysis) are usually used to identify factors affecting house prices and to quantify their influence. This requires large quantities of good-quality data – such as cross-sectional or time-series data on property values and characteristics in a well-defined area – and statistical expertise.

The environmental attributes and ESs that can be valued using a hedonic approach are limited to those that people pay attention to when house-buying. If people are unaware of the influence an environmental attribute or ES can have on their quality of life, it will not be reflected in house prices.

The hedonic-pricing approach can be used for purposes other than valuing ESs. Khan (2012), for example, used hedonic pricing to analyse the determinants of catfish (*Pangasius* spp.) prices in Barishal district (Bangladesh) (see module 6, Box 25). Haque, Faisal and Bayes (1997) applied the hedonic-pricing method to estimate the loss of human health and land values due to a deteriorating environment caused by pollution from tanneries in Dhaka. Mottaleb, Sene and Mishra (2016) used hedonic pricing to analyse the impact of remittance incomes on house prices in Bangladesh.

Indirect methods: using surveys to elicit information

Indirect methods, also known as "stated preferences", involve the eliciting of individual valuations/preferences through surveys in which respondents are asked hypothetical questions on their WTP for certain ESs. The two most commonly used indirect methods for valuing ESs are **contingent valuation** and **choice modelling**.

Contingent valuation

Contingent valuation measures people's WTP for increasing the provision of an ES, or alternatively, their willingness to accept (WTA) losses or degradation (Pascual and Muradian, 2010). The method can be used for estimating both use and passive-use values and, in principle, it can estimate all TEV components. It is implemented though surveys and a range of elicitation methods, including the following (Mitchell and Carson, 1989):

- Open-ended – "*How much would you pay to restore forest X?*"
- Single bound dichotomous choices – "*Would you be willing to pay an additional USD 5 in income tax to restore forest X?*"
- Double bound dichotomous choices – "*Would you be willing to pay USD 10 to restore forest X? If YES, would you pay USD 15? If NO, would you be willing to pay USD 5?*"
- Payment card – respondents pick a value from those given on a card.

Box 21 summarizes the six main steps in contingent valuation. Examples of contingent valuation in Bangladesh include a CBA to determine the economic efficiency of the restoration of the Buriganga River (Alam, 2008) and the economic valuation of flood-risk exposure and flood control in the country's southeast (Box 22).

BOX 21

The six main steps for implementing a contingent-valuation study

1. Design survey

- Start with focus-group sessions and consultations with stakeholders to define the ES to be valued.
- Decide the nature of the market – that is, determine whether the ES is being traded; the baseline (i.e. current) situation in terms of quantity, quality and frequency of the ES; who benefits; and the level of improvement or deterioration of the ES to be valued. Ensure that the expected change (either improvement or deterioration) is clearly stated and understandable. The change should be relevant and perceptible compared with the baseline, and the timescale (i.e. when the change will occur) should be made clear.
- Determine the quantity and quality of information available on the ES in question, who will pay for it, and who will benefit from it.
- Set the allocation of property rights (which determines whether a WTP or WTA scenario is involved).
- Determine a credible scenario and payment vehicle (e.g. tax, donation or market price) and ensure that respondents have enough information to properly understand these.
- Decide the elicitation method (e.g. dichotomous choice or open-ended elicitation). Referendum-like (dichotomous) questions (e.g. yes/no; take/leave) are usually preferred.
- Develop a questionnaire. Typically, this is organized into three main sections: 1) an introduction describing the ES to be valued and its features and presenting any other useful information to respondents (e.g. the aim of the research and why it is important); 2) a central section, including the elicitation mechanism for collecting information on WTP or WTA (this section should highlight expected/desired changes in the ES and explain the way by which payments might be made. It should take into consideration any constraints due to the income of respondents and make clear the consequences for the ES if payments are not made); and 3) a final section that collects socio-economic information from respondents, such as on gender, age, income level and education.

2. Implement survey using sampling

- On-site, face-to-face interviews should be used in preference to other options (e.g. mail, phone, internet or group), although they are more expensive and time-consuming. Researchers or specialist companies may conduct the interviews.
- Various sampling approaches can be used, such as convenience, representative or stratified.
- Inform survey respondents about budget constraints and investment trade-offs. Each investment (e.g. the creation of a protected area) will reduce the resources available for other purposes.
- Inform respondents about substitute sites/alternatives, such as existing protected areas and those under creation.
- Include check-questions to verify that respondents have understood correctly (e.g. whether they know what a protected area is and the specific protected area(s) in question).

Box 21 continues on next page

Box 21 continued

3. Calculate measures of welfare change

- Open-ended – simple mean or trimmed mean (in the latter, outliers are removed; note that trimming is contentious).
- Dichotomous – estimate the expected value of WTP or WTA.

4. Technical validation

Most contingent-valuation studies attempt to validate responses by investigating how the respondents' WTP (or WTA) relates to environmental or socio-economic attributes.

5. Aggregation and discounting

Calculate the total WTP using the mean or median WTP and the size of the relevant population (e.g. by multiplying the sample mean WTP of visitors at a site by the total number of visitors per year). Discount the calculated values, as appropriate.

6. Study appraisal

Test the validity and reliability of the estimates generated.

Source: Modified from Kontoleon and Pascua (2007); Mavsar (2004).

BOX 22

Economic valuation of flood-risk exposure and flood control in Bangladesh

Brouwer, Aftab and Haque (2006) performed an economic valuation of flood-risk exposure and flood control in the Homna subdistrict, approximately 70 km north of Dhaka. The area under study consists of a floodplain delta covering 10 000 ha bordered by the Meghna River and its tributaries to the northwest, the Titas River to the north and south and the Kathalia River to the west. The topography varies between 1.5 m and 4 m above sea level. Average annual precipitation is 2 025 mm, mostly (75 percent) in the monsoon period from June to October. Heavy rains cause flooding almost every year, inflicting widespread damage on houses, agricultural crops and infrastructure. The Homna subdistrict is one of the most severely affected areas in terms of the percentage area inundated, the depth of inundation (≥ 2 m) and the percentage of people affected. About 400 000 people live in the area, most of whom are farmers. About 75 percent of the land is used for farming: rice is the main crop, followed by wheat, vegetables, oil seeds and maize, and there is also some small-scale livestock farming. Communities of fishers use rivers, creeks and canals.

The study surveyed about 700 local people living without flood protection along the Meghna River and its tributaries about their preferences for a flood-mitigation scheme. Using the contingent-valuation method, respondents were asked (in face-to-face interviews) to indicate their WTP to reduce current and future flood risks. The survey collected socio-economic information (e.g. age, gender, income, education and occupational activities) about respondents and their opinions on the importance of reducing flood exposure

Box 22 continues on next page

Box 22 continued

risks. To assess WTP, respondents were first asked about their WTP "in principle" for a flood-protection scheme; those who responded positively were then asked for a specific bid amount using a dichotomous-choice approach. The questionnaires emphasized that the money would be used solely to finance the construction of embankments in the area. Ten bid levels were used – BDT 10, 20, 50, 100, 200, 500, 1 000, 2 000, 3 000 and 5 000 per household per year – and dichotomous choice was used as the elicitation method. The bid amounts, which were determined in a pilot test of the survey, were allocated randomly among respondents. Respondents were also asked to indicate why they would or would not be willing to pay the given amount. To check WTP stability over time and the reliability of the study, a follow-up survey was carried out six months after the first on a sample of about 80 randomly selected respondents.

The survey found that the average annual household income among respondents was about USD 950, with half of the surveyed households having an average income of less than USD 560. The average annual per capita income was calculated at USD 150, which was less than the national average income at the time of the survey (USD 325). About 55 percent of respondents were living below the poverty threshold (USD 105 per capita per year). More than 96 percent of respondents said they were exposed to flooding each year, of whom about 75 percent indicated that such flooding inflicted damage on houses, crops and fishponds (resulting in losses of fish stock); had health consequences (diarrhoea) needing medical treatment; and caused loss of income from day labour and trade. The average cost of flood damage was estimated at USD 190 per household per year (with a range of USD 0 to USD 16 000) – that is, about 17 percent of average annual household income.

About 80 percent of respondents considered that flood protection was important or very important. Only 5 percent, however, indicated that local residents should pay for flood control (i.e. the embankments proposed by the survey). Ninety-four percent of respondents considered that the central government (82 percent of respondents) or foreign aid agencies (12 percent) should pay for it.

Around 40 percent of respondents reported that they would be willing to pay "in principle" for a flood-protection scheme in the area. Most (80 percent) of those who gave a negative reply said they would not pay because of financial/income constraints (this was checked and found to be true).[39] These respondents were asked if they would be willing to contribute "in kind" to the flood-protection scheme: about 40 percent said they would be, mostly through their own labour, as part of their harvest or (in 5 percent of cases) by giving up part of their land for the construction of embankments. About 20 percent of those who said they would be unwilling to pay for a flood-protection scheme due to insufficient financial resources indicated that the central government was responsible for flood control and should pay for it (such people were categorized as protest bidders).

A total of 488 valid observations for the second-step WTP questions (i.e. the dichotomous-choice exercise) were collected. Not including zero bidders from the first WTP question, the average WTP for the flood-protection scheme was in the range of 0.25 and 0.34 percent of average

Box 22 continues on next page

39 An unwillingness to pay corresponds with a legitimate "zero" bid.

Box 22 continued

household income (i.e. USD 2.42–3.21 per year). If, conservatively, the lower percentage was adopted, this would correspond to an aggregated value for the 33 640 households living in the area of USD 81 409 per year.

The survey findings indicate that the WTP of local residents should incorporate both monetary and non-monetary (e.g. in-kind) values. The relatively low WTP might be influenced not only by income constraints but also by the fact that about one-fifth of respondents reported that flooding is an unavoidable natural event and more than 90 percent indicated that the central government – ultimately with the help of foreign aid agencies – should pay for the work. The study also found that the economic value of flood-risk exposure may already have been capitalized in property prices because a positive relationship was found between reduced risk exposure and property prices.

Although some studies have supported the validity and reliability of contingent valuation (OECD, 2006), efforts are still ongoing to improve the robustness of the methodology (Price, 2014). Among its main limitations, the familiarity of respondents with the good or ES being assessed, and their understanding of the issue about which they are being interviewed, are crucial and should not be assumed. Many factors may produce biased responses. For example, respondents might provide protest replies (e.g. they might value the ES but dislike certain scenarios, such as the use of a tax to extract payments); give strategic bias to influence the outcome of the survey; or show information bias due to a lack of information on what is to be valued. Another common bias is the so-called "warm-glow effect" (Andreoni, 1990): people feel good about the act of giving for a social good (like an ES), not (just) because they value the good. People also tend to behave differently depending on whether they are making hypothetical or actual decisions: if respondents know they are not really going to pay, they might provide unrealistic values or not take the exercise seriously. Respondents might also make associations among ESs: for example, if requested to express their WTP for increased visibility in a landscape due to a reduction in air pollution, they might respond based on health issues related to air quality. WTP can be influenced by the list position of the ES to be valued (an "ordering" problem), the payment vehicles indicated (e.g. there may be a higher WTP for donations compared with taxes), and the starting bid. Moreover, WTP tends to be lower than WTA; in the case of direct-use values, it might also decrease with the distance of people from the ES being valued (distance decay).

Choice modelling

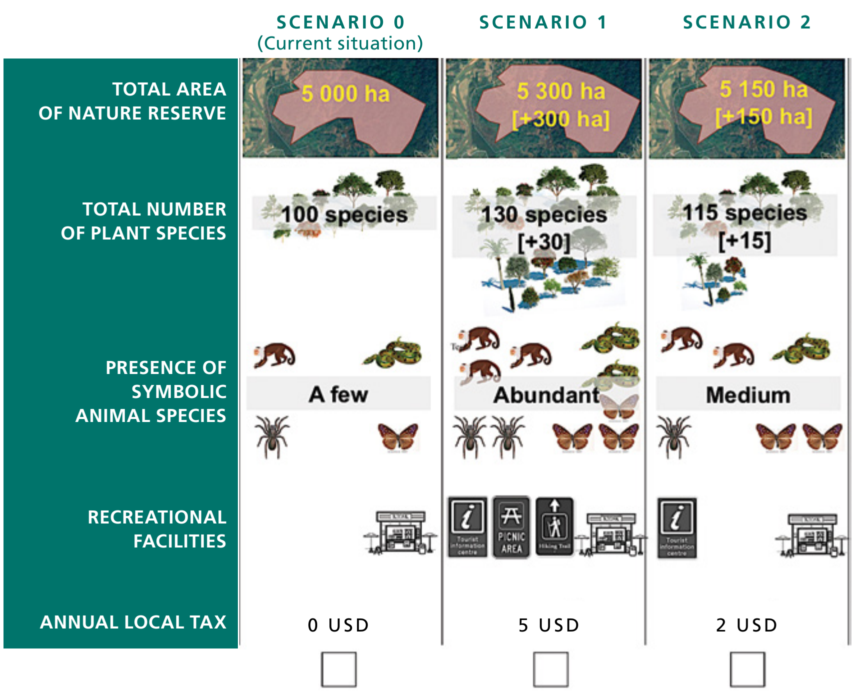
Choice modelling (or choice experiments) is a survey-based method in which people are asked to choose among alternatives associated with different attributes (e.g. ESs). The method can be used to estimate monetary values and rank options. WTP for the various attributes (and their combinations) can be estimated by varying the levels of attributes in different scenarios (choice sets), associating a monetary value with each combination of attributes, and examining respondents' choices through appropriate analysis. The rationale behind choice modelling is that policy choices and the benefits and costs arising from them imply (positive or negative) changes in environmental resources or ESs. Valuation exercises therefore involve quantifying the value of those changes (Heal *et al*., 2005).

Each respondent addresses one or more choice sets (in most cases 3–16). Normally a "status quo" option (reflecting the existing situation) is included. Figure 26 shows an example of a choice set presenting three scenarios describing various options for the management of a nature reserve. One scenario constitutes the baseline (current situation) and the other two are associated with incremental variations of several attributes (i.e. the size of the reserve, the total number of plant species, the presence or abundance of certain animal species, and the number and type of recreational facilities).

Each scenario is associated with a different economic value representing an annual local tax that respondents would hypothetically be requested to pay should they choose a certain scenario.

Data collected through choice-modelling surveys are analysed with econometric tools – usually involving special software – to determine both the marginal value of each attribute and the total value of a scenario through the aggregation of attribute values.

FIGURE 26
A choice set for choice modelling



Choice modelling is a powerful tool for assessing people's WTP for the increased delivery of ESs arising as a result of changes in policy or management. Respondents are requested to think in terms of trade-offs, and usually visual means (such as photographs and graphics) are used to help them understand the options they are being asked to assess. Respondents may find this approach easier than being asked to directly attach a monetary value to a single scenario (e.g. in contingent valuation). Because the economic value is embodied within scenarios as an attribute, however, it might make respondents more comfortable to highly rate scenarios that bundle ESs rather than focusing on price. Some trade-offs might not be easy to evaluate if respondents are not familiar with the issues behind them, potentially biasing the responses. Contingent choice might also extract preferences in the form of attitudes rather than behavioural intentions, especially if respondents feel that the exercise is purely hypothetical. Finally, the number of choice sets and scenarios offered can strongly affect results and should be managed carefully. Providing too many choice sets might make the survey overly complex, with the risk that respondents become fatigued and, as a consequence, adopt simplified selection rules when responding. On the other hand, providing too few options might mean that respondents are forced to choose options they would not make voluntarily (Mavsar, 2004).

Choice modelling (as well as demand-curve approaches in general) requires specific skills and expertise and is usually time- and resource-consuming. It has been used to estimate socio-economic values in different forest contexts and on multiple topics, such as the valuation of street trees (Giergiczny and Kronenberg, 2014); the assessment of the willingness of buyers of forest ESs to consider the distributional impacts of payments to local suppliers (Randrianarison and Wätzold, 2017); biodiversity valuation in the Mekong delta (Khai and Yabe, 2014; Khai, 2015) (Box 23); the valuation of ESs and forest attributes in mountain forest areas (Gatto *et al.*, 2014); and estimating demand for forest certification (Jaung *et al.*, 2016). See Bennet and Birol (2010) for examples of case studies using choice experiments in developing countries.

BOX 23

The economic valuation of biodiversity conservation in swamp forests in the Mekong delta, Viet Nam

Khai and Yabe (2014) investigated the economic value of biodiversity conservation in the U Minh Thuong National Park, a large peat swamp forest area in the Mekong delta, Viet Nam, with the aim of informing policymakers on welfare losses due to biodiversity reductions.

The park covers 8 038 ha, and another 13 069 ha serve as a buffer zone. The park is home to many animal and plant species, including 40 species listed on the International Union for Conservation of Nature's Red List of Threatened Species. Although it has been declared a protected zone, the park is subject to several threats, including forest encroachment for agriculture and urban development, poaching, the intensive use of chemicals for agriculture, and industrial waste.

Through a choice-modelling exercise, the study proposed the creation of a fund for biodiversity conservation in the area, with the aim of increasing the number of flora and fauna species or at least preventing their decline. The conservation activities that would be covered by the fund included management planning of shrimp ponds and rice farming around the buffer zone to prevent water pollution and food scarcity; tree planting to support nesting and – more generally – better habitat for wildlife; increasing forest cover to reduce soil erosion; and education and training to increase the awareness of local people about biodiversity conservation. The attributes to be used in the choice experiment (and their levels) were selected using focus groups of local experts and researchers and tested in a pilot survey of about 50 local respondents. The five attributes were: 1) percentage of vegetation with good health status; 2) the number of mammal species; 3) the number of bird species; 4) the number of reptile species; and 5) the number of farmers becoming worse off (in terms of welfare losses). Voluntary continuous donations made through monthly water bills over three years were used as the payment method. Possible payment amounts were: USD 0.47; USD 1.66; USD 2.84; USD 4.21; and USD 5.20. Twenty-five choice sets were created (see Table 8 for an example) and used in face-to-face surveys. Each questionnaire featured five choice sets and three alternatives (one being the status quo). The questionnaires also collected information on the socio-economic profiles of respondents (e.g. age, gender, education and income) and checked their familiarity with basic issues related to biodiversity. Respondents were given information on the existing condition of the park, especially its biodiversity status, before they began answering questions.

A total of 366 respondents were surveyed. Results showed that older respondents were more likely than younger respondents to prefer the status quo. Consistent with other studies, higher levels of education and income, and greater familiarity with biodiversity issues, were associated with a higher WTP. The marginal WTP – that is, the amount of money respondents were willing to pay to trade off for a per-unit improvement in an environmental attribute or to prevent welfare losses among farmers – varied by attribute and attribute quantity, except for welfare losses for farmers (stable marginal WTP). Thirty-four percent of respondents were willing to pay for the proposed conservation measures – that is, they selected an alternative

Box 23 continues on next page

Box 23 continued

to the status quo at least once. WTP was mostly dependent on an increase in the health status of vegetation and the number of mammal species, as well as on the prevention of welfare losses among local farmers. In particular, respondents were willing to pay USD 0.043 per month per household for an increase of 1 percent in the area of vegetation with good health status; USD 0.017 per month per household for one additional mammal species; and USD 0.115 per month per household to prevent welfare losses among 100 local farmers.

TABLE 8. **An example of a choice set used in the survey on the economic value of biodiversity conservation in the U Minh Thuong National Park, Viet Nam**

Attribute	Alternative A (status quo)	Alternative B	Alternative C
Vegetation with good health status (%)	60	80	90
No. of mammal species	30	45 (+15)	60 (+30)
No. of bird species	150	210 (+60)	170 (+20)
No. of reptile species	45	85 (+40)	105 (+60)
No. of farmers worse off	0	800 (+800)	1 200 (+1 200)
Surcharge on household water bill (USD)	0	4.21	5.20

Source: Khai and Yabe (2014).

4.3 BENEFIT TRANSFER

Benefit transfer comprises methods that rely on the "use of research results from pre-existing primary studies at one or more sites or policy contexts (often called study sites) to predict welfare estimates or related information for other, typically unstudied sites or policy contexts (often called policy sites)" (Rolfe *et al*., 2015). In other words, it is the process of taking study results from one situation and extrapolating them to other similar situations (Figure 27).

FIGURE 27
Benefit transfer: transferring values from the study site to the policy site

Assume, for example, that, as a result of field and desk research at forest site A (the study site), the following annual values have been determined: USD 100/ha for timber production; USD 150/ha for non-timber forest production (e.g. herbs and fruits); and USD 50/ha for carbon sequestration. If forest A covers 100 ha, the total value of the three ESs combined would be USD 30 000 (i.e. USD 300/ha × 100 ha). The unit values can be transferred as such, or through adaptation, to forest site B (the policy site), which provides the same three ESs. If forest site B covers 250 ha, its total value would be USD 75 000 (i.e. USD 300/ha x 250 ha).

Benefit transfer is used mostly when time, budgetary, data-availability and technical or other constraints prevent the use of primary data in performing estimates (mainly, it is quicker and cheaper than primary studies). Although the use of good-quality primary data is widely seen as best for estimating values (Allen and Loomis, 2008), policy realities often mean that benefit transfer is the only feasible option (Johnston and Rosenberger, 2010).

The main benefit-transfer methods (Table 9) are as follows (Bartczak, Lindhjem and Stenger, 2008):

1. **Unit value transfer** is a single-point benefit-transfer approach, of two main types
   a. **simple** (or naïve) **unit value transfer** – value(s) estimated at the study site are transferred as such to the policy site; and
   b. **adjusted** unit value transfer – adjustments are made to value(s) estimated at the study site before they are transferred (for example, adjustments based on income).
2. **Function transfer** transfers entire functions, thus allowing the use of multiple bits of information to adjust values estimated at the policy site. A specific (regression) function is used together with information on parameters/variables (e.g. substitute sites and environmental and population characteristics) to transfer values. This allows the calibration of values according to selected characteristics of the policy site. Further distinction is made between:
   a. **benefit function transfer**, which transfers values estimated at a *single* study site to the policy site; and
   b. **meta-analytic benefit transfer**, which transfers values estimated at *multiple* study sites to the policy site.

TABLE 9. **Overview of benefit transfer methods**

Unit value transfer	
Simple (naïve) **unit value transfer** $WTP_s = WTP_p$	**Adjusted unit value transfer** $WTP_s = WTP_p(Y_p/Y_s)^{\beta}$
Notes: WTP = willingness to pay; s = study site; p = policy site; Y= income level; β = income elasticity of demand for the non-market commodity evaluated.	
Function transfer	
Benefit function transfer (single study) $WTP_i = a + bX_{ij} + cY_{ik} + dS_{il} + e_i$	**Meta-analysis benefit transfer** (multiple studies) $WTP_r = a + bX_{rj} + cY_{rk} + dS_{rl} + fZ_{rm} + u_r$
WTP_i = WTP of respondent i; X_{ij} = site and good characteristics j, Y_{ik} = respondent characteristics k; S_{il}= substitute site characteristic l; e = random error; WTP_r = mean WTP for study r; Z_{rm}= study characteristics m; u = random error; a, b, c and d = parameters.	

Source: Modified from Bartczak, Lindhjem and Stenger (2008).

Box 24 and exercise 7 give examples of simple and function benefit transfer. Box 25 contains an example of a meta-analysis benefit transfer involving ES values for mangroves in Southeast Asia.

BOX 24

Simple unit benefit transfer

Mangrove forests perform substantial provisioning services for fisheries (see section 4.1). Based on the methodology developed by Barbier (2000) for assessing the value of mangroves for fisheries in Thailand, it has been estimated that if the number of fishers was stable and the area of mangroves increased by 10 percent, the fisheries harvest would increase by 1 percent. The same methodology was used to estimate the value of mangroves for inshore fishing in the Ngoc Hien area, Viet Nam.[40] In that case, it was estimated that a 1 percent increase in the area of mangroves would cause a 1.96 percent increase in aquaculture production. Using data on aquaculture production, market values for aquaculture products, and variation in the area of mangroves over time, the study found that a 1-ha increase in mangrove area would increase the value of aquaculture production by USD 187 per year.

A quick estimate of the value of mangrove afforestation can be made for the Sundarbans in light of the above-reported examples. According to data seen in Uddin *et al.* (2013), 4 600 tonnes of fish are harvested per year from about 410 000 ha of mangrove forests in the Sundarbans. A survey done by one of the authors of this manual in late 2017 revealed that collectors receives a price of USD 0.73 per kg of fish collected in this forest area. By using this price and data from Uddin *et al.* (2013), we can estimate that the total value of fish collected from the Sundarbans is USD 3.4 million per year (USD 732 per tonne and USD 8/ha). Assuming that a 1 percent increase in the area of mangroves corresponds with a 1.96 percent increase in fishery production, a 4 100-ha increase in mangrove area in the Sundarbans would produce an additional 90.16 tonnes of fish per year, equivalent to an additional USD 65 971 – that is, about USD 16 per year for each ha afforested.

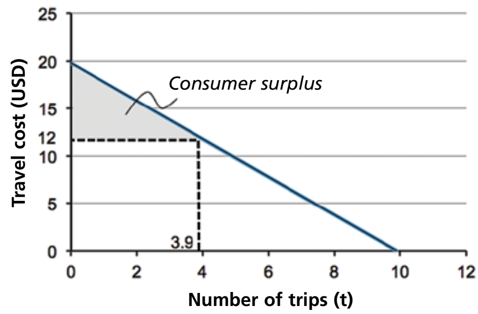
40 Nunes and Varma (2015) used the methodology developed by Barbier (2000) to estimate the value of an increase in mangrove area in terms of potential aquaculture production.

Exercise 7. **Single unit and function benefit transfer**

Nature reserve A (100 ha) attracts local visitors interested in nature photography and wildlife sightseeing. The recreational value of the reserve has been estimated using the individual travel-cost method,[41] as follows (see also Figure 28):

- Average travel cost per trip = USD 12.
- Average number of trips per visitor per year = 3.9.
- Estimated consumer surplus per visitor = USD 46.80.
- Estimated number of visitors per year = 1 000.
- Total estimated consumer surplus per visitor = USD 15.21.
- Total estimated annual value of reserve A = USD 15 210 (USD 152.1/ha).

FIGURE 28
Consumer surplus per visitor per year for nature reserve A



Nature reserve B is similar to A but in a different region. The distance to urban areas is similar to that for nature reserve A. It can be assumed, therefore, that the average travel cost per trip will be the same for A and B. Reserve B is smaller (95 ha) and better conserved than A; the average number of wildlife viewings per visit is higher in B (seven per visit, on average, based on existing studies, compared with three per visit in A). The average number of visitors to B is 900 per year. The recreational value of B is estimated below using simple unit value transfer and benefit function transfer.

1. Simple unit value transfer

The consumer surplus per visitor estimated for nature reserve A (study site) is directly transferred to reserve B (policy site). Therefore, the total estimated annual value of B is USD 15.21 x 900 = USD 13 689 per year (about USD 144.1/ha). B has a lower value than A by this methodology because it receives fewer visitors.

Exercise 7 continues on next page

[41] Modified from Johnston et al. (2015).

Exercise 7 continued

2. Benefit function transfer

An analysis of data collected in a travel-cost survey for nature reserve A finds that the number of trips is given by the following linear model:[42]

$$t = 0.1 - 0.5\,(TC) + 0.0001\,(INC) + 0.5\,(VIEW) + 0.5\,(SC)$$

Where: t = number of trips per visitor per year; TC = average travel cost per trip; INC = average annual income of visitors; $VIEW$ = average viewings of wildlife species per visit; and SC = cost of travelling to the nearest substitute site.

Table 10 shows data for the two reserves.

TABLE 10. **Travel costs, income, number of rare species, and the cost of closer substitute sites for nature reserves A and B**

Variables	Reserve A	Reserve B
Travel cost per trip (TC) (USD)	12	12
Income (INC) (USD/person per year)	23 000 Data collected in survey and confirmed by census figures for the corresponding region	25 000 Data collected from census figures for the corresponding region
No. of rare species viewed per visit (VIEW)	3	7
Travel cost to closest substitute site (CS) (USD) (based on distance)	12	12

Applying the above model to nature reserve B:

$$t = 0.1 - 0.5\,(TC) + 0.0001(25\,000) + 0.5(7) + 0.5(12)$$

$$\text{i.e. } t = 12.1 - (0.5)\,(TC)$$

Thus, the number of trips is:

$$t = 12.1 - 0.5(12)$$

$$\text{i.e. } t = 6.1$$

The consumer surplus per visitor is USD 37.21 (Figure 29), giving a total value for nature reserve B of USD 33 489 (USD 352.5/ha). Benefit function transfer highlights differences between the two reserves in terms of the number of wildlife viewings and the average income of the local population. According to this method, Reserve B has a higher value than A (and higher than the value calculated using the simple unit value transfer method).

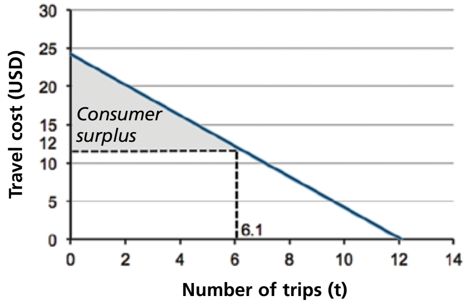
Exercise 7 continues on next page

[42] This model is for illustrative purposes only.

Exercise 7 continued

FIGURE 29

Consumer surplus per visitor per year for nature reserve B (Benefit function transfer)



BOX 25

Valuing ecosystem services provided by mangroves in Southeast Asia using a meta-analysis benefit transfer

Bramnder *et al.* (2012) investigated the value of change in ecosystem services (ESs) due to the loss of mangrove forests in Southeast Asia (i.e. Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, the Philippines, Thailand and Viet Nam) in a business-as-usual scenario (2000–2050) using meta-analysis benefit transfer combined with spatial data on changes in mangrove area. They conducted a broad literature review that encompassed more than 40 studies in online journal databases, libraries, online valuation reference inventories and interviews with experts. The collected studies contained estimates for mangrove study sites around the world (with a focus on Southeast Asia) based on various methodologies and approaches. The studies reported values that could be standardized to an annual monetary value per unit area (USD/ha per year at 2007 prices) and contained data on the explanatory variables included in the meta-regression function used for the meta-analysis. Explanatory variables used as determinants of variation in mangrove value included: characteristics of each mangrove site (size of mangrove area in ha); biophysical context characteristics (total area of mangrove sites within 50 km of each study site, and density of the road network within 50 km); and socio-economic characteristics (population within 50 km and GDP per capita). The average mangrove value determined from the selected studies was USD 4 185/ha per year.

The estimated meta-regression double log model showed that:

- The unit value of mangroves (i.e. per ha) was lower in larger areas of mangroves than in smaller ones. Thus, adding 1 ha to a large expanse of mangroves was less valuable than adding 1 ha to a smaller area. Model outputs showed that a 10 percent increase in mangrove area produced a 3.4 percent decrease in unit value.

Box 25 continues on next page

Box 25 continued

- The extent of mangroves close to study sites had a positive influence on their economic value. Thus, as the area of mangroves within 50 km of the study site increased, so too did the value of the study site due to greater connectivity and complementarity between mangrove patches. A 10 percent increase in the area of mangroves within 50 km increased the value of the site by 2.5 percent. This also implies that isolated mangrove patches have lower value than intact, contiguous mangrove forests.
- A higher road density was associated with lower mangrove value. The model found that a 10 percent increase in road density corresponded with a 3.1 percent decrease in mangrove value – due probably to the fragmentation of the resource by roads and other infrastructure.
- The value of a mangrove resource increases with increasing nearby population and GDP. According to the model, a 10 percent increase in population corresponded with a 2.8 percent increase in the unit value of mangroves, and a 10 percent increase in GDP corresponded with a 7.9 percent increase in the unit value of mangroves.

The study included a comparative analysis of a baseline scenario in 2000 (current situation) and a future scenario to 2050 developed according to the GLOBIO[43] model. It assumed a 35 percent decrease in mangrove area (a decline of about 2 million ha) in Southeast Asia between 2000 and 2050, driven mainly by aquaculture development. The study estimated the annual value of lost ESs due to mangrove clearing in the region over the period at about USD 2.16 billion in 2050. Assuming that mangrove losses occur linearly over the period, the present value of lost ESs was estimated at USD 40 billion at a discount rate of 1 percent and USD 17 billion at 4 percent. Indonesia and Malaysia would incur the highest losses, at USD 1.7 billion and USD 279 million per year, respectively.

The choice among the various types of benefit transfer is influenced by factors such as the information and studies available, the type of value required, the general similarity (or correspondence) between the study and policy sites, the expertise of researchers and analysts, the time and resources available to develop transfer methods, and the precision necessary for different types of policy decision (Johnston *et al*., 2015).

When performing benefit transfer, use can be made of databases of existing valuations and studies as sources for the values to be transferred to the policy site(s). The databases include the following:

- Environmental Valuation Reference Inventory (www.evri.ca)
- ENValue (www.environment.nsw.gov.au/envalue)
- Ecosystem Service Valuation Database (www.es-partnership.org)
- Earth Economics Ecosystem Valuation Toolkit (www.esvaluation.org/index.php)
- Catalogue of Assessments on Biodiversity and Ecosystem Services (http://ipbes.unepwcmc-004.vm.brightbox.net).

[43] www.globio.info

For the market values of certain ESs (e.g. carbon sequestration, water-based ESs, and biodiversity), use can be made of Forest Trends' Ecosystem Marketplace[44] publications and studies. In addition to databases, one-off studies and reports can be considered for additional site-specific inputs, although extracting data might be time- and resource-consuming. In some cases, technical reviews of ES valuation studies are available (e.g. TEEB, 2010a; Smajgl, 2015).

Implementing benefit transfer involves the following five steps (Rolfe *et al*., 2015):

1. Frame the scope of the benefit-transfer exercise. This includes identifying the ESs to be valued and the features of the ecosystems providing them (e.g. forest type and composition, forest area and local characteristics).
2. Identify relevant existing studies for the same (or similar) ESs and ecosystems, for example through a search in the scientific and grey literature and the above-mentioned databases of valuation studies.
3. Evaluate the applicability of the studies identified in step 2 to the policy site – that is, whether values are transferable. Such an evaluation should consider the quality of the studies (e.g. Is it mentioned or used in other studies? Did it use a sound, consistent methodology?). Reflect on the similarity between the potential study site and the policy site and, more generally, on the context in which the existing studies were developed and the one in which the valuation will take place. Other factors to consider include the purpose of the studies (e.g. estimating environmental damage and compensation or for academic research), their geographical scope, site size, baseline conditions (e.g. ecosystem quality), the methodology applied, year, and the demographic and socio-economic conditions of investigated areas.
4. Choose the benefit-transfer method. The choice will depend on factors such as the similarity between the study and policy sites, the quality of available studies, the availability of data for adjustments, the level of accuracy required, and time and budgetary constraints. Usually, the unit value transfer is appropriate if the required level of accuracy is low and the available resources are limited.
5. Implement the benefit-transfer method. This usually includes adjusting values from existing studies, taking into account differences between sites in, for example, GDP, income, education, extent, the presence of substitute sites, and the ESs under investigation.

Although benefit transfer can be time- and cost-efficient, it must be conducted carefully to avoid misuse and misinterpretation. It has been subject to considerable research since the 1990s, and attention has been paid to the development of methods, procedures and protocols (Johnston and Rosenberger, 2010). Nevertheless, many caveats remain which, if not properly managed, can lead to inaccurate estimates and, ultimately, to inappropriate decisions and policies.

[44] www.ecosystemmarketplace.com

4.4 SUMMARY COMPARISON OF ES VALUATION METHODS

Table 11 provides a summary comparison of the valuation methods presented, their rationale, degree of complexity and conditions for implementation, and the type(s) of ESs they suit best.

TABLE 11. **Summary comparison of ecosystem service valuation methods**

Group		Method	Rationale and description	Complexity and conditions	Best-suited ecosystem services (ESs)
Direct market price		Market price	Reference is made to observed market prices for the goods or services to be estimated (or those of similar goods or services)	• Simple • Active, reliable, accessible markets must be in place	Provisioning (e.g. timber, woodfuel, wild forest products, drinking water) Some regulating (e.g. carbon markets)
Market value analysis	Benefits as proxy	Opportunity cost	Value foregone to protect, enhance or create a particular environmental asset	• Relatively simple • Active and reliable market for foregone values/goods/ services	Provisioning (e.g. woodfuel, drinking water) Regulating (e.g. habitat conservation)
		Production function	ESs are considered as production factors/inputs to a production process and their value is inferred by considering changes in the production process of market goods that result from an environmental change (e.g. change in pollination reflected in agricultural crop production)	• Complex • Requires clear and well-known relationship between the ESs under study and the production of a market good or service • It is possible to isolate and model the effects of changing levels of ESs on the production of a market good or service	Provisioning (e.g. water for irrigation) Regulating (e.g. pollination, maintaining nursery populations and habitats)

Table 11 continues on next page

Table 11 continued

Group		Method	Rationale and description	Complexity and conditions	Best-suited ecosystem services (ESs)
Market value analysis	Costs as proxy	Replacement cost	The cost of replacing or restoring a damaged asset (e.g. burnt forest) to its original state is considered a measure of the benefits of restoration	• Simple • Requires active, reliable, accessible markets for goods/inputs • The fact that an ecosystem is eliminated/altered and the related ESs are reduced does not mean that people are demanding or are willing to pay for restoration/replacement	Potentially all ESs, but disaggregating the values of individual ESs might be difficult
		Cost of substitute goods	The market value of an alternative artificial good or service (substitute or surrogate) is attributed to an ES	• Simple • Requires active, reliable, accessible markets for substitute goods and services • Depends on the effectiveness of substitutes in providing the same functions as the ESs being valued • The fact that an ecosystem is eliminated/altered and the related ESs are reduced does not mean that people are demanding or are willing to pay for their substitution • Minimum estimate (i.e. natural ecosystems might provide multiple ESs)	Provisioning (e.g. drinking water, fodder) Regulating (e.g. defence against floods, storms, landslides and tidal surges)
		Defensive expenditure	The value of the defence against natural hazards (e.g. floods, storms, climate change and temperature increases) provided by ecosystems can be estimated based on the expenditure incurred in avoiding or reducing the effects of a negative externality or to reduce or compensate for damage incurred from such an externality	• Relatively simple • Active, reliable, accessible data are available on defensive expenditure • Might be data-demanding • Defensive expenditure might serve multiple purposes (risk of overestimation)	Regulating
		Damage and insurance costs	The value of ESs providing defence against natural hazards can be estimated based on expenditure that would be (or has been) incurred if damage occurs and from expenditure on insurance payouts	• Relatively simple • Active, reliable, accessible data are available on damage and insurance costs • Might be data-demanding	Regulating

Table 11 continues on next page

Table 11 continued

Group		Method	Rationale and description	Complexity and conditions	Best-suited ecosystem services (ESs)
Demand-curve approaches	Indirect methods	Travel cost (individual/ zonal)	Estimated on the basis of the cost of visiting a site, including travel costs (e.g. fares, car use, public transport and entrance fees) and the opportunity cost of time	• Relatively complex • Only provides direct-use value • Data- and resource-demanding (especially in the individual version)	Cultural (especially recreation)
		Hedonic pricing	The effects of environmental attributes and other features influence the market price of certain goods and services (e.g. environmental quality and landscape amenity influence house prices)	• Complex • Data- and resource-demanding • Requires active, reliable, accessible markets for goods and services (e.g. houses) linked to the environmental attributes being assessed	Mainly cultural (e.g. landscape amenity and environmental assets such as air quality and peacefulness)
	Direct methods	Contingent valuation	Survey-based approach that constructs hypothetical markets – respondents answer survey questions to indicate their WTP for a particular change in an ES	• Complex • Data- and resource-demanding • Respondents must be familiar with the ES under study • Potentially biased if surveys (and later analysis) are not conducted properly	Potentially all
		Choice modelling	Survey-based approach: respondents are requested to choose among choice sets presenting different levels of ESs. Each choice set is associated with a price or value that enables the estimation of respondents' WTP	• Complex • Data- and resource-demanding • Requires appropriate econometric experience and skills	Potentially all
Benefit transfer		Unit (simple or adjusted) Function, meta-analysis	The transfer of study results from one situation (study site) to another, similar situation (policy site), with adjustments	• Simple (unit) to complex (function/meta-analysis • Requires the existence of studies/values to be transferred (database) • Similarity between study and policy sites	Potentially all (as long as values are available for the study site)

Source: Modified from TEEB (2010b).

Different valuation methods can be used separately or in combination, depending on the situation and the ESs to be assessed. Exercise 8 provides an example of ES valuation for the coastal afforestation project described in scenario 1 (see section 1.2), and Exercise 9 provides an example of valuation approaches and methods that can be adopted to estimate the environmental costs associated with scenario 5.

Exercise 8. **Cost–benefit analysis for a coastal afforestation project (scenario 1)**

A 17 000-ha coastal afforestation project[45] is planned in southern Bangladesh. Afforestation will use various species, and it will feature 1 000-km strip plantations for timber and woodfuel.

The costs associated with afforestation include:

- planting (about USD 0.125/seedling). Associated labour costs are assumed to be 33 percent of the total planting costs;
- replanting to "fill in" gaps due to seedling mortality: 20 percent of originally planted seedlings need to be replaced at year 1; and
- maintenance (for the strip plantations only, at years 1 and 2). Associated labour costs are assumed to be 90 percent of the total maintenance costs.

To take into account the opportunity cost of unskilled labour in the area, a 0.75 coefficient is used for the economic analysis, which is calculated by dividing the shadow daily wage for unskilled labour (USD 1.87) by the market wage (USD 2.50).

The harvesting costs for strip plantations are also taken into account. Indirect costs include the opportunity cost of land use, which is the value of foregone activities and land uses – mainly grazing – in the afforested areas. It is projected that grazing will be restricted in the first three years of afforestation (planting and maintenance). Based on field surveys, it is estimated that 2 000 bags of fodder are produced per ha per year. At a market value of USD 0.20/bag, the total gross value of fodder grazed in the area is USD 400/ha. An estimated 60 working days per year are dedicated to fodder production. At a daily rate of USD 2.50, the total cost of labour is USD 150/ha. Thus, the net value of fodder is USD 250/ha per year. It is estimated that 7 500 ha are dedicated to grazing.

Monitoring and administrative costs to ensure that the project is properly implemented are also taken into account.

The expected benefits arising from the afforestation project comprise:

- *timber and woodfuel production* from plantation strips (harvested once every ten years). Based on similar projects and local market prices, the following values are assumed:
    - poles – 7 m^3/km, USD 0.90/pole
    - sawlogs – 18 m^3/km, USD 160/m^3
    - woodfuel – 11 m^3/ha, USD 60/m^3.

Additional timber and woodfuel production from thinning is not considered.

- Based on similar projects and existing literature, non-wood forest products are expected to generate USD 87/ha on about 6 300 ha of mangrove forests, starting in year 4.
- *Offshore fisheries* will be supported by the presence of mangrove forests introduced by afforestation. Based on similar projects and existing literature, the benefits are estimated at USD 45/ha, starting in year 4.

Exercise 8 continues on next page

45 Data are modified from World Bank (2017b).

Exercise 8 continued

- The value of *protection against storms* is estimated based on the role of coastal mangroves in averting deaths and house damage caused by super cyclones. It has been estimated that planted mangroves could help save 84 lives at a probability of 10 percent in year 4.[46] It is assumed that the protective role of mangroves will decrease proportionally with the trend of more robust and resilient houses and the increasing presence of cyclone shelters. It has been estimated that 1 ha of mangrove forests would avert USD 716 of housing damage,[47] starting in year 4 and increasing by 0.5 percent per year due to population growth (+1 percent per year) and a consequent increase in the number of houses.

A discount rate of 10 percent is used for the CBA (assuming that the project is supported financially by a development bank). A time horizon of 30 years is set to account for both market and non-market benefits.

Table 12 presents the present values and cost–benefit indicators for the afforestation project.

TABLE 12. **Present values and cost–benefit parameters for a hypothetical coastal afforestation project in southern Bangladesh**

Costs	USD
Afforestation	4 758 000
Opportunity cost of land	5 130 000
Monitoring and administrative costs	429 000
Total costs	**10 317 000**
Benefits	**USD**
Timber and woodfuel	3 172 000
Non-wood forest products	6 513 000
Offshore fishery	3 328 000
Cyclone protection (averted deaths)	6 045 000
Cyclone protection (averted house damage)	3 094 000
Total benefits	**22 152 000**
Net benefits (net present value)	**11 835 000**
Benefit/cost ratio	2.15
Internal rate of return	18%

The investment is economically profitable because the NPV is positive (+USD 11.8 million) and the benefit/cost ratio is 2.15. The IRR of 18 percent is higher than the discount rate used for the analysis.

Exercise 8 continues on next page

[46] Data adapted from Das and Vincent (2009).
[47] Data adapted from Das and Vincent (2009).

Exercise 8 continued

The project will be able to ensure a flow of benefits as long as afforested areas are maintained over time. The effects of deforestation on the project's economic performance can be tested through a sensitivity analysis that assumes an increasing annual rate of deforestation and an associated decrease in benefits. As shown in Table 13, the sensitivity of project efficiency to a decrease in forest area due to deforestation is evident: every 1 percent increase in the annual deforestation rate would result in about a 1 percent decrease in the project's IRR.

TABLE 13. **The internal rate of return associated with annual deforestation rates of 1–5 percent**

Annual deforestation rate (%)	Internal rate of return (%)
1	17.0
2	15.9
3	14.7
4	13.6
5	12.4

Exercise 9. Approaches and methods for estimating environmental costs associated with the construction of a large power plant (scenario 5)

The construction of a large coal-based power plant has been proposed in the proximity of the World Heritage-listed Sundarbans Forest Reserve. Given the size of the plant (more than 1 200 megawatts) and the concerns expressed by many stakeholders about environmental impacts, the Bangladesh Forest Department has been requested to assess the environmental costs. These have been classified into two main groups: those associated with plant construction, and those associated with management.

In each group, various potential costs have been identified and appropriate valuation approaches and methods proposed. Table 14 summarizes the results.

Environmental costs include those associated with the impacts arising from extreme natural events –especially cyclones, which are common in the area and which could damage the plant and cause water and soil contamination.

Social costs such as those associated with increased exposure to health risks should also be taken into account. For example, there may be increased mortality and morbidity due to the inhalation of airborne pollutants: this could be valued based on the estimated cost of treatments and income losses due to sick leave.

Exercise 9 continues on next page

Exercise 9 continued

TABLE 14. **Summary of affected ecosystem services, the expected impacts, and valuation approaches that could be used to estimate costs**

Affected ecosystem service/ environmental aspect: CICES Section	Affected ecosystem service/ environmental aspect: Type	Expected impact	Valuation approach(es)
1. Plant construction			
Provisioning	Agricultural crops Timber Woodfuel Fish	An area of about 750 ha will be developed for construction of the plant and its facilities. Estimated permanent lost annual production of: • 1 300 tonnes rice • 560 tonnes fish • 100 m³ timber • 50 tonnes woodfuel	• Direct market price (from the closest marketplace) • Alternatively: opportunity cost of substitutes (for woodfuel) • Alternatively: opportunity cost of time (for woodfuel collection and rice cultivation elsewhere)
Regulating	Carbon sequestration	Avoided carbon sequestration due to land-use change. Additional environmental costs due to emissions associated with building operations and transportation activities	• Direct market price for carbon (lost sequestration potential) • For emissions: social cost of carbon (see Harris, 2016)
2. Plant management			
Provisioning	Agricultural crops Fish	An area in a 10 km radius (31 400 ha) around the plant is considered the "impact area" affected by plant operations due to airborne pollutants. It is expected that there will be a 50% decline in crop yields and fish production compared with the following baseline: • 62 000 tonnes rice per year • 130 000 other crops per year • 5 300 tonnes fish per year	• Direct market price (from the closest marketplace) • Alternatively: opportunity cost of substitutes or time (for cultivating rice and other crops elsewhere)
Regulating	Carbon sequestration	Environmental costs due to emissions associated with the use of coal and the transportation of coal to the plant	• Social cost of carbon (see Harris, 2016)
	Water quality	About 5 000 m³ per hour of water (of 9 000 m³ per hour extracted) will be released back to a local river. Discharged water will include hazardous chemicals (e.g. heavy metals) and will increase the temperature of river water. There will be water pollution associated with coal transportation and waste disposal	• Defensive expenditures (e.g. water treatment costs based on available market prices and/or similar cases or studies)

Table 24 continues on next page

Exercise 9 continues on next page

Exercise 9 continued

Affected ecosystem service/ environmental aspect		Expected impact	Valuation approach(es)
CICES Section	Type		
Regulating	Salinity regulation/ control	About 4 000 m^3 per hour net water extraction from a local river, with impacts on downstream water volume and salinity	• Defensive expenditures (e.g. cost of limiting salinity to existing concentrations based on available market prices and/or similar cases or studies)
	Habitat/ species conservation	Impacts on species and habitat due to the spread of pollutants, increased water temperature, acidification, eutrophication, noise, etc.	• Reproduction costs for the restoration of affected habitats and species
Cultural	Tourism	Given the proximity of the plant to the reserve, it is expected that it will cause a decline in the number of visitors due to reduced environmental quality. A 5–10% reduction in tourism is expected, based on the size of the impact area and building on existing literature	• Benefit transfer of average unit value per visitor, based on existing studies

4.5 A WORD OF CAUTION

Identifying and measuring the quantity and quality of ESs and estimating their value pose many difficulties. Despite the growing body of literature on ESs, many challenges and gaps remain (De Groot *et al*., 2010). Existing economic tools do not permit the reliable monetary valuation of all ESs. In certain cases, monetary valuation may be unnecessary or even counterproductive, especially if it is seen as contrary to cultural norms or fails to reflect a plurality of values (TEEB, 2010a). No single, all-encompassing method exists, and valuations vary depending on the method used. Some approaches (e.g. stated preferences) have shortcomings, and estimating unbiased values (e.g. how to phrase questions and provide information to respondents) and accurately separating WTP for various ESs pose challenges (Price, 2014). There are also ethical concerns, such as those associated with the commoditization of ESs and the "financialization" of nature from a solely anthropocentric point of view (Kill, 2014). Financialization can be interpreted both narrowly (e.g. the market trading of ESs) and (building on Epstein, 2002) broadly as the "entire process of increasing influence of financial actors, institutions, markets and thinking over society's perception of and approach to nature" (Kill, 2014).

Uncertainty is a crucial issue in the valuation of ESs in the form of:

- **supply** – there is a lack of understanding of the link between ecosystem functions, ESs and the tangible benefits these provide for humans;

- **preferences** – the uncertainty of respondents in stating their preferences, especially when they are not fully informed about what they are being requested to value or when the good or service to be valued is unfamiliar or intangible; and
- **technical aspects** – uncertainty about the accuracy of valuation outputs and the effects of discounting future values (Pascual and Muradian, 2010).

Other important issues and challenges include the following (Pascual and Muradian, 2010; Animon, Matta and Pettenella, forthcoming; Ring *et al.*, 2010; De Groot *et al.*, 2010):

- **Accounting suitably for interdependence within and between ecosystems**. A policy affecting forest-related ESs might have consequences for other ecosystems (e.g. timber harvesting might affect water regimes, thus affecting wetland conservation).
- **Trade-offs among ESs.** Various ESs are bundled together, and all ESs may be affected if there is a change in one. Some ESs co-vary positively (e.g. more of one means more of another): for example, soil protection can promote primary production, increase carbon storage in biomass and hence improve climate regulation, while also contributing to provisioning ESs (e.g. food and fibre production). Some other ESs co-vary negatively: for example, strongly increased forest harvesting may reduce biodiversity and favour soil erosion on steep slopes.
- **Spatial scale.** The benefits and costs related to ES management might not occur over the same area. For example, the increased use of chemical inputs to boost crop production can decrease water quality, thus affecting communities downstream. Although an ecosystem's functioning and ability to deliver ESs are often best evaluated for relevant ESs, these may not coincide with the spatial scale of the evaluation (due, for example, to technical, budgetary or time constraints, and information gaps). Another issue is that the optimal scale of assessment and valuation can vary according to the ESs being assessed. For example, water-related regulating ESs should be valued at the watershed scale, while other regulating ESs, such as carbon sequestration, can be valued at the scale of a single forest stand but also at the national or even global scales.
- **Temporal scale**. The impacts on ecosystems, and the ESs they deliver, can extend beyond the period used for the valuation, requiring the collection of appropriate information to enable an understanding of how ESs may change over time and affect the valuation. Moreover, costs and benefits might not occur at the same time: this can be managed by discounting future costs and benefits to the present. Although discounting can reduce temporal uncertainty, there is room for discussion on technical and ethical issues associated with discounting (e.g. What is an appropriate discount rate? Is discounting always appropriate?).
- **Variability of value among groups.** ESs are usually ranked in their relative importance and valued differently by individuals and groups depending, for example, on income level, dependence on ESs for their livelihoods, and physical distance from the source of the ESs. Figure 30 depicts the valuation of different ES categories within the framework of TEV, considering spatial and temporal variability.

- **Thresholds and limits.** Ecosystems have a certain level of resilience[48] to pressures (Holling, 1973), but persistent or strong drivers can cause ecological deterioration beyond critical thresholds, thus leading to permanent changes ("regime shifts"; Folke *et al*., 2004) that affect the quality or quantity of the ESs being delivered.[49] Such non-linear changes increase the marginal value of ESs in ways that an economic valuation might not fully capture. Economic valuation requires adequate understanding of how ecosystems and their components contribute to the production of ESs, including knowledge of ecosystem thresholds and related uncertainties. An understanding is needed of how ecosystem functions can change temporally and spatially and how this affects the quantity and quality of ESs. The uncertain future losses associated with potential changes can be assessed through sensitivity analyses.
- **Cumulative effect.** When a natural resource is abundant, marginal small-scale changes due to individual decisions (e.g. urban development at the expense of natural forests) may be negligible on their own. If made repeatedly and independently of each other, however, this will affect the total value of the resource due to the cumulative effect of those changes arising from a decline in the connectivity of the resource. An analysis of the effect of individual decisions on the total resource is needed to better understand cumulative effects and the marginal cost of using a resource. Considering the cumulative impacts at the level of a programme may change the cost–benefit relationship compared with that estimated at the scale of single decisions (DEFRA, 2007). Exercise 10 provides an example of this linked to scenario 4.
- **Uncertainties and gaps in the monetary valuation of a single ES.** Valuation methods have been refined in recent decades, and the number of valuation studies has increased tremendously. Nevertheless, bias may still exist in the use of various valuation methods. This may depend on the nature of the methods, and some forms of bias may arise from the way in which a method is implemented (e.g. systematic and non-systematic errors, data quality, the level of accuracy in data analysis, and output interpretation). In some cases, studies covering the same geographical area, ecosystems and ESs might not be fully consistent in terms of, for example, their approaches and methods, spatial and temporal scales, and assumptions. Such studies might provide researchers and policymakers with considerable information but also leave them uncertain about how to use it (e.g. Kandel *et al*., 2016).

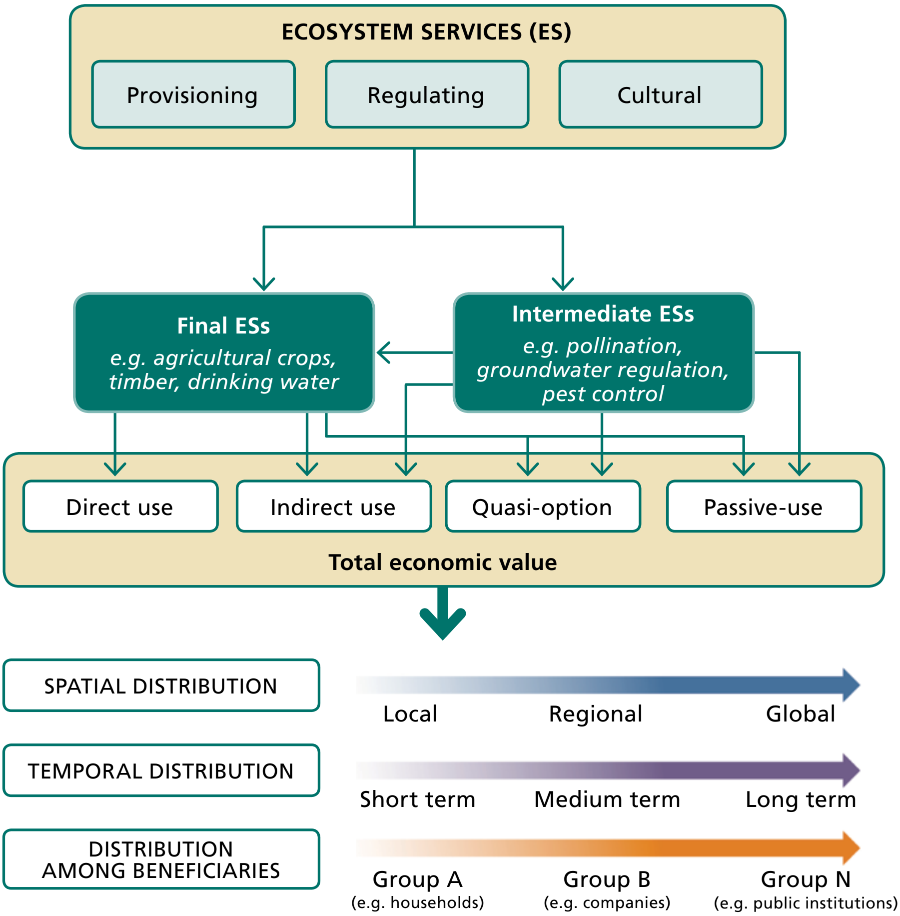
Sound science is essential for generating strong evidence, and care needs to be taken in attributing values to natural capital when other inputs (e.g. labour) are also involved. Valuation is an important tool for policymaking; nevertheless, in light of the challenges described above, it should be viewed as just one input to decision making (DEFRA, 2007).

[48] Ecosystem resilience is the "capacity of a system to absorb and utilise or even benefit from perturbations and changes that attain it, and so to persist without a qualitative change in the system" (Holling, 1973).

[49] A database of thresholds and regime shifts in ecological and linked social-ecological systems is available at www.resalliance.org.

FIGURE 30

The valuation of ecosystem services – ecosystem service types, components of total economic value, and distributional effects



Source: Modified from Zandersen *et al.* (2009).

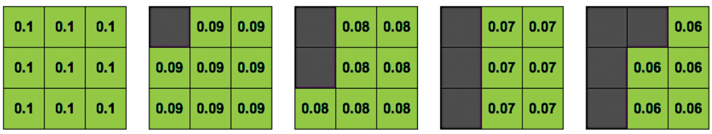
Exercise 10. **Cumulated effects on the value of ecosystem services of converting a green area (scenario 4)**[50]

In reference to the development of the green area considered in scenario 4 in section 1.2, assume that the size of the area is 9 ha and an ES valuation exercise resulted in a TEV of USD 0.9 million, or USD 0.1 million/ha.

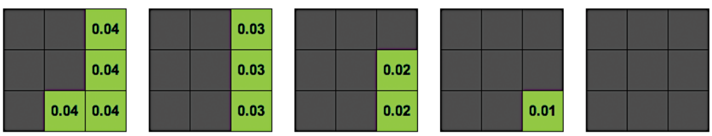
Local people and users attribute value to the area because of its scenic beauty and peacefulness, being far away from traffic, noise and pollution. As a consequence, the development of one part reduces the value of the rest of the area. Assuming that, if 1 ha is developed, the value of the remaining 8 ha diminishes by USD 0.011 million/ha, the cost of developing 1 ha is equal to USD 0.1 million + USD 0.011 million x 8 ha = USD 0.19 million (figures 31 and 32). In deciding whether to proceed with the conversion, decision makers should consider this total cost.

FIGURE 31

Effects of development on the unit and total value of the green area considered in scenario 4, and unit and total costs associated with development



Developed area (ha)	0	1	2	3	4
Average value of remaining green area per ha (million US$/ha)	0.10	0.09	0.08	0.07	0.06
Marginal cost of loosing 1 additional ha green area (million US$/ha)	0.20	0.19	0.18	0.17	0.16
Total value of remaining green area (million US$)	0.90	0.71	0.54	0.40	0.28
Cumulative cost of loosing 1 ha of green area (million US$)	0.00	0.19	0.36	0.50	0.62



Developed area (ha)	5	6	7	8	9
Average value of remaining green area per ha (million US$/ha)	0.04	0.03	0.02	0.01	0.00
Marginal cost of loosing 1 additional ha green area (million US$/ha)	0.14	0.13	0.12	0.11	0.10
Total value of remaining green area (million US$)	0.18	0.10	0.04	0.01	0.00
Cumulative cost of loosing 1 ha of green area (million US$)	0.72	0.80	0.86	0.89	0.90

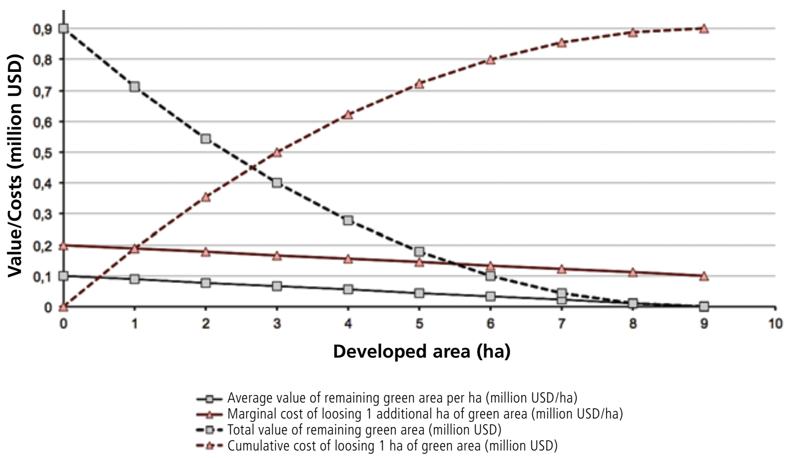
Exercise 10 continues on next page

[50] Modified from DEFRA (2007).

Exercise 10 continued

When development proceeds and the green area is increasingly converted, the average value of undeveloped parts diminishes, together with the marginal costs associated with the development of each additional ha. This shows the importance of the first development decision because it is very likely to influence decisions on whether to continue developing the area or to conserve it.

FIGURE 32
Marginal and total values/costs associated with the conversion of the green area considered in scenario 4



Reflection point

Consider the area you analysed for the reflection points in Module 2. For each ES you listed, report at least one method you would adopt to perform a valuation. Indicate and discuss the pros and cons associated with each method by considering whether it would be appropriate and feasible (in particular if relevant data would be accessible). Discuss the findings with your colleagues.

Table 15 lists the ESs generated in a hypothetical natural forest.

TABLE 15. **The ecosystem services generated in a natural forest in the ABC Forest District**

Ecosystem service according to the Common International Classification of Ecosystem Services				**Valuation methods**	**Pros/cons**
Section	Division	Class	Ecosystem service (ES)		
Provisioning	Food	Wild animals and their outputs Wild plants, algae and their outputs	Game and wild forest products (e.g. herbs, wild fruit)	Market prices Opportunity cost Demand-curve approaches (direct methods; e.g. contingent valuation)	*Market prices:* only some of the forest products produced in the forest (game and some wild fruit) are sold in local markets. Market values would need to be adjusted because they would not cover the cultural value of traditional products. *Opportunity cost:* reference could be made to the opportunity cost of either buying products in the market or collecting products in nearby forests. *Demand curve* (e.g. contingent valuation): data-demanding and probably more costly than alternative methods. Expertise is needed. This approach could allow the inclusion (to some extent) of the cultural value of ESs
Provisioning	Materials	Fibres and other materials from plants, algae and animals for direct use or processing	Timber	Market prices	*Market prices:* data are available and accessible for timber assortments gathered in both natural forests and plantations
Provisioning	Energy	Plant-based resources	Woodfuel	Market prices Opportunity cost	*Market prices:* there is a very limited market for woodfuel in the area because it is normally produced and collected for self-consumption. *Opportunity cost:* reference could be made to the opportunity cost of either collecting woodfuel in nearby forest areas or using alternative fuels (e.g. kerosene)

Notes: Selected ecosystem = natural forest. This is a hypothetical situation.

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Module 5 | Provisioning services

KEY MESSAGES

- Although a large number of studies have estimated monetary values for provisioning ESs, not all such ESs are traded on the market.
- The provisioning ESs of forests play crucial roles for rural people, for example by providing food, building materials, medicines and fuel.
- In Bangladesh, forest-based provisioning ESs include timber, woodfuel, other wild forest products (e.g. honey, wax and herbs), and drinking water, among others.
- Tools are available for obtaining information on, for example, the forest products collected by people; the time spent on collection; and the sources of such products. These tools include guidance on socio-economic surveys in forestry developed jointly by FAO, the Center for International Forestry Research, Institut Français des Relations Internationals and the World Bank.
- Provisioning ESs are valued mainly using methods involving market values, including the direct use of market values, opportunity cost, and the cost of substitute goods. The use of demand-curve methods for estimating provisioning ESs is much less common (and advisable) because such methods are data- and resource-demanding and require appropriate econometric skills.
- Examples are provided with reference to woodfuel (market value and the opportunity cost of substitute goods and time) and wild forest products.

Provisioning ESs include all physical products and materials obtained from ecosystems, such as timber, food and woodfuel. Because they represent tangible and visible outputs, the identification and quantification of provisioning ESs is generally easier than for other ESs. Tools are available to collect information on the products people collect, the time spent in their collection, and the sources from which they are obtained. For example, FAO *et al.* (2016) developed guidance and modules for socio-economic surveys in forestry.

A large number of monetary values for provisioning ESs are estimated in the literature (Pascual and Muradian, 2010), but not all provisioning ESs are traded in the market. When markets exist, they may be informal or not fully transparent (e.g. markets for wild forest products). The valuation of provisioning ESs mostly takes into consideration use values, particularly direct-use (consumptive) values, but – in principle – passive-use values could also be considered.

Table 16 shows some key forest-based provisioning ESs in Bangladesh, as reported in Barua, Boscolo and Animon (2017) based on available literature.

TABLE 16. **Main forest-based provisioning ecosystem services in Bangladesh, by forest zone**

Section	Division	Forest zones in Bangladesh				
		Sundarbans	Coastal	Village	Sal	Hill
Provisioning	Nutrition	Honey, fish, shrimps, potable water and crabs [**]	'Potable water [**]'	Cultivated fruit, vegetables and spices [**]	Cultivated fruit, vegetables and spices [**]	Potable water [***], cultivated and wild fruit, vegetables and spices [**]
	Materials	Wax, thatching materials and medicinal plants [*]	Timber, medicinal plants, fodder and thatching materials [**]	Timber, bamboo, medicinal plants and handicraft-making materials (e.g. cane, murta[51] and hogla[52]) [***] Groundwater and fodder [**]	Medicinal plants and groundwater [**] Timber and bamboo [*]	Timber, bamboo, medicinal plants, cane, gum and groundwater [**]
	Energy	Woodfuel and biomass [**]	Woodfuel and biomass [**]	Woodfuel and biomass [***]	Woodfuel and biomass [*]	Woodfuel and biomass [**]

Level of importance: * = low; ** = medium; *** = high.
Source: Barua, Boscolo and Animon (2017).

5.1 AVAILABLE METHODS

In most cases, provisioning ESs can be directly or indirectly linked to market values; thus, market-value analysis can be used in their valuation (see sections 4.1 and 4.4, especially Table 11).

Whenever a (local) market exists, such as for timber, woodfuel, bamboo and certain non-wood forest products, local prices should be considered, net of production costs such as those associated with harvesting and transportation to the marketplace. Some costs may be informal but should still be taken into account. They may comprise in-kind payments (e.g. by the provision of labour, or harvest-sharing), and, in some cases, they may involve informal fees paid at checkpoints (Hou *et al.*, 2010) and other informal payments to officials (Islam and Sato, 2012). Informal or even illegal harvesting activities should be fully taken into account when assessing the value of ESs because they might significantly affect the quantity of ESs actually supplied (and thus the total value). By influencing supplied quantities and production costs, illegal activities can also affect prices (often lowering them).

51 Murta (*Schumannianthus dichotoma*), which grows in wetland areas of Bangladesh, is used for various purposes, including the manufacture of prayer and bed mats. On average, 100 ha of murta is worth USD 91 783 per year, rising to more than USD 353 000 per year after processing. Murta processing and trade can generate income for each farmer household of up to USD 216 per year (Ahmed et al., 2007).

52 Hogla (*Typha elephantina*) is used in rural floodplain areas of Bangladesh for thatching, fodder, fencing and fuel. According to Uddin *et al.* (2006), farmers can earn, on average, USD 5 per decimal of land (i.e. per 1/100 acre, or approximately 40.46 m^2) per year.

If products are aimed at self-consumption rather than commercial sale, market prices can be used for estimating opportunity costs (i.e. the costs of foregone money).

There may also be opportunity costs involved in the use of substitute goods and time (e.g. the cost of time foregone in collecting a forest good rather than spending it on other activities, such as paid work or education).

When the collection or harvesting of provisioning ESs implies payment of access or collection fees, such payments can be used to generate rough estimates of the value of the ESs themselves. This is the case, for example, for honey and wax collection in the Sundarbans forests, where access payments are made to the competent authorities (Partha, 2016; Uddin *et al*., 2013). This approach is likely to underestimate the value of ESs, however, for several reasons: it does not cover informal activities not captured by formal channels (e.g. people may access the resource illegally or harvest more than they are allowed) (Islam *et al*., 2012); access fees are set administratively and may not reflect the value of the ESs; and, in certain circumstances, the collection of wild products might be associated with recreational experiences that provide benefits to collectors and are valued as such[53] (although this is not the situation for honey and wax harvesters in the Sundarbans). In such cases, the payment of fees would include both the value attributed to provisioning ESs (wild products) and cultural ESs (recreation, and leisure from the recreational experience), and it would be difficult to distinguish between them.

In principle, provisioning ESs can also be estimated through the cost of substitute goods. For example, the value of potable water provided by a spring can be estimated as the cost of buying bottled water instead. Similarly, the value of fodder provision can be estimated as the cost of alternative animal feedstock, and the value of thatching materials can be estimated as the cost of substitute roofing materials. In most cases, this valuation method is the same as the above-mentioned opportunity-cost approach for substitutes.

The use of demand-curve approaches for estimating provisioning ESs is rare, presumably due to the additional effort and cost involved. Gunawardena, Edward-Jones and McGregor (1999) used the contingent valuation method to estimate the option and existence values of Sri Lanka's Sinharaja Rainforest Reserve, including the valuation of certain provisioning ESs such as woodfuel and wild forest products.

Like all other ESs, provisioning ESs can be estimated using benefit transfer. This requires caution, however, and the adoption of the procedures outlined in section 4.3.

5.2 EXAMPLES

The provisioning ESs provided by forests and other ecosystems are the most studied because of their importance to local livelihoods. Bamboo, woodfuel and an array of other products contribute to the livelihoods of many Bangladeshi. Two examples of provisioning ES are described here: 1) woodfuel; and 2) wild forest products (honey and wax). In the final example, the opportunity-cost method is used to assess the economic attractiveness of a plantation as opposed to an alternative agricultural use.

[53] For example, this is the case for mushroom-picking in many Mediterranean countries.

Woodfuel

Biomass is the primary source of energy for rural households in Bangladesh, with more than 80 percent of households relying on biomass for cooking (WHO, 2016). Homestead forests supply more than 90 percent of the woodfuel demand (Hassan *et al.*, 2012). The country consumes an estimated 59 million tonnes of woodfuel per year, at an average per capita consumption of 0.171 m^3 per year (Barua and Kumar, 2016), mainly for cooking, rice parboiling and occasional heating (Hassan *et al.*, 2012). The role of homestead forestry, village forests and roadside plantations in biomass production for energy has been well reported (e.g. Islam *et al.*, 2012; Foysal *et al.*, 2014; Muhammed *et al.*, 2011; Rahman *et al.*, 2015).

The value of woodfuel can be estimated using market values through the **opportunity-cost approach** (e.g. the **opportunity cost of substitutes** or the **opportunity cost of time** – that is, the time that would be spent collecting woodfuel from other, further-away forests).

Using market values

Woodfuel (as well as timber) is used for self-consumption and sold in local markets, where prices depend on species, quality and region. The Bangladesh Bureau of Statistics[54] reported that the average price for 1 quintal (i.e. 100 kg) of *Shorea robusta* woodfuel in 2015–2016 was BDT 655.69, equivalent[55,56] to USD 61.20/m^3.

Using the opportunity cost of substitutes

Woodfuel is valued here in terms of the value of its closest substitute – dried cattle dung. In this example, the opportunity cost of using dung instead of wood can be estimated in the reduced agricultural crop production caused by diverting manure from fertilizer use to energy. It has been estimated that 1 m^3 of woodfuel is equivalent to 0.6 tonnes of dried cattle dung, which is generated from 2.4 tonnes of fresh manure (Fleming, 1983). The application of 1 tonne of manure to a certain crop would increase production by 20 percent, from 1.5 tonnes/ha to 1.8 tonnes/ha. If the market price for the crop is USD 0.19/kg (i.e. USD 190/tonne), the opportunity cost of missed crop production would be:

$$(1.8\ tonnes - 1.5\ tonnes) \times USD\ 190 = USD\ 57/ha.$$

Using the conversion factor from fresh manure to woodfuel, the opportunity cost of lost woodfuel production would be $57 \div 2.4 = USD\ 23.75/m^3$. This corresponds with the cost of giving up fresh manure as a fertilizer to use it as a fuel in the absence of woodfuel.

[54] See: www.bbs.gov.bd
[55] BDT 1 = USD 0.013
[56] A market price of BDT 655.69/quintal is equivalent to USD 8.52/quintal and USD 0.85/kg.
Assuming a density for *Shorea robusta wood* of 720 kg/m^3 (see www.fao.org/docrep/w4095e/w4095e0c.htm), $USD\ 0.85/kg \times 720\ kg/m^3 = USD\ 61.20/m^3$

Using the opportunity cost of time

Values for woodfuel can be estimated based on the value of the time that household members spend collecting and carrying woodfuel from the closest forest (Figure 33). If, on average, a household collects 20 kg of woodfuel per 8-hour day on 50 days per year, 400 hours would be dedicated to woodfuel collection per year. At 20 kg per day over 50 days, 1 000 kg of woodfuel would be collected per year. Assuming an average wood density of 500 kg/m^3, the volume of woodfuel collected in one year would be 2 m^3 (i.e. 1 000 kg ÷ 500 kg). Women perform most woodfuel collection (Hassan *et al*., 2012), and a woman's average wage is estimated at BDT 25 per hour. Thus, the total opportunity cost of time (i.e. if the time spent on woodfuel collection was dedicated to paid labour) would be $BDT\ 25 \times 400\ hours = BDT\ 1\ 000$ (about USD 130). The opportunity cost of time per unit of woodfuel collected would be USD 130 divided by 2 m^3 = USD 65/m^3.

Table 17 summarizes woodfuel values estimated using three different approaches.

FIGURE 33
The opportunity cost of time associated with woodfuel collection

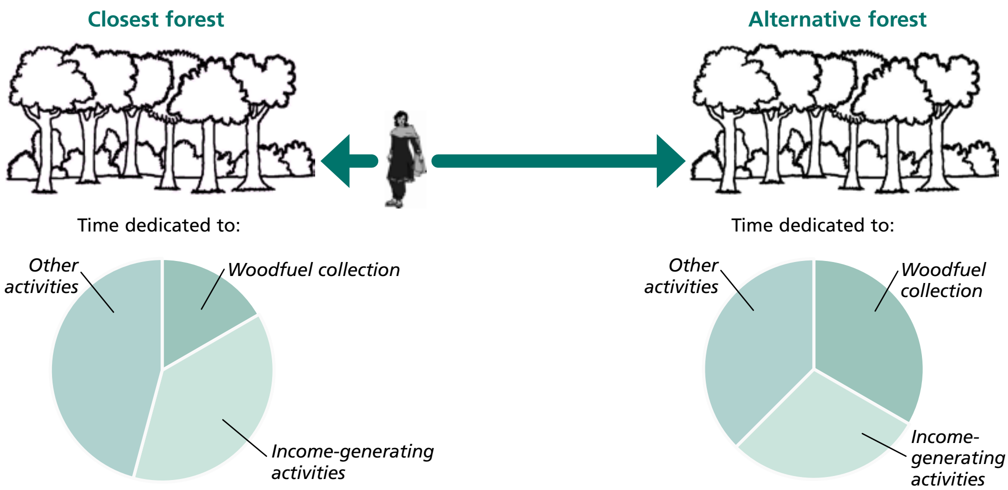


TABLE 17. **Woodfuel values for Bangladesh, estimated by three different methods**

Market value	Opportunity cost of substitutes	Opportunity cost of time
Shorea robusta woodfuel in Dhaka market = USD 61.34/m^3 (2015–2016)	Assuming dried cattle dung is used as a substitute = USD 23.75/m^3	Assuming woodfuel is collected by women in the closest forest area = USD 65/m^3

Several factors should be taken into account in choosing the methodology for estimating woodfuel value. If a market for woodfuel exists and is accessible (in terms of distance, but also based on the average income of local households), the market-value approach should be preferred, taking into consideration the opportunity cost of time spent travelling to the marketplace. If there is no market or it is not fully accessible, alternatives should be considered. If substitute products are available and can realistically be used as fuel, estimates of the opportunity cost of substitutes can be used. If substitutes are unavailable but woodfuel collection is possible (and performed) in other places, the opportunity cost of time is likely to be a suitable option. It is advisable to use opportunity costs (either of substitutes or time) as a cross-check for estimates based on market value.

Wild forest products: honey and wax

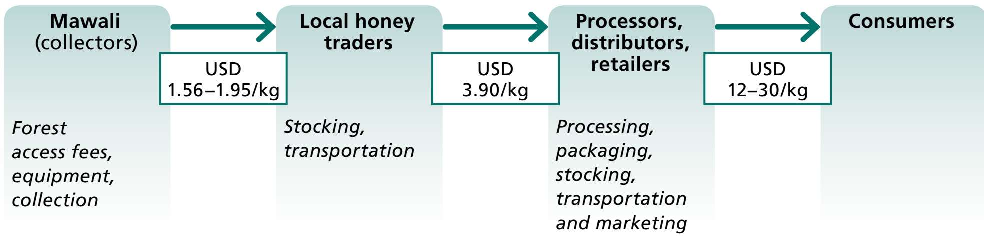
The Sundarbans is one of Bangladesh's main natural-honey production areas, producing about 75 percent of the country's supply from giant bees (*Apis dorsata*) (Moniruzzaman and Rahman, 2010). Traditional honey and wax collectors known locally as Mawali operate in a short season of 2.5 months, starting in March/April (Rahman and Asaduzzaman, 2010). Each forest-dependent community may obtain a single permit for honey collection from the local office of the Forest Department, along with a boat licence certificate (BLC) to allow a boat containing up to nine collectors to enter the Sundarbans. The cost of one BLC is BDT 7 000 (about USD 91), and each harvester is allowed to collect no more than 75 kg of honey per season (Partha, 2016).

Based on Forest Department data, Uddin *et al.* (2013) estimated that annual honey and wax production in Sundarbans forests in 2001–2010 ranged between 32 and 128 tonnes,[58]. These are likely to be underestimates, however, because they do not consider illegal honey harvesting reported in other studies (Islam *et al*., 2012; Denzau and Denzau, 2010).

Estimating the actual value of honey production based on market prices is not easy because prices vary significantly depending on market stage and actor and are influenced by transaction costs such as those associated with intermediation, transport, processing and stocking (Figure 34). Partha (2016), for example, reported that Mawali sell *khalisa* honey (honey produced between March and May) for BDT 120–150/kg (USD 1.56–1.95/kg), but local honey traders sell the same product at BDT 300/kg (USD 3.9/kg). Honey is sold in Dhaka shops for USD 12/kg. Sundarbans honey is sold on the internet at prices as high as BDT 1 950–2 350/kg (USD 25.35–30.55/kg).

[57] According to the Forest Department, honey production has decreased in recent years. See: www.dhakatribune.com bangladesh/2016/11/05/28768/ [58] BDT 1 = USD 0.013

FIGURE 34
Value chain of honey from the Sundarbans: actors and their main activities and sales prices



These estimates do not include the risk-related costs and negative externalities associated with honey harvesting. Honey collection in the Sundarbans has been called "perhaps the most dangerous job in the world"[58] because of the risk of attack by tigers, venomous snakes, crocodiles and bandits (Partha, 2016). Gani (2001) reported that, on average, four Mawali are killed each year by tigers, which is about 25 percent of the average total number of people killed by tigers each year in the Bangladesh Sundarbans (Barlow, Ahmad and Smith, 2013).

Estimating the opportunity cost of creating a forest plantation

Exercise 11 explores the opportunity cost of creating forest plantations by comparing the potential household-level returns from planting trees and harvesting forest products with the potential returns from producing agricultural crops.

[55] www.bbc.com/news/13556336

Exercise 11. Estimating the household opportunity cost of planting trees

Efforts to create (or maintain) forest areas at the expense of agriculture require that households give up the earnings they might otherwise receive from annual agricultural crops. In this exercise you will estimate the opportunity cost of creating forest plantations by comparing the potential household-level returns from planting trees and harvesting forest products with the potential returns from agricultural crops.

Two land-use options are considered.

- Option 1: Acacia forest plantation (a rotation period of 15 years), intercropped in the first three years with cassava. Table 18 shows the costs and revenues associated with this option.

TABLE 18. **Hypothetical costs and revenues associated with an acacia forest plantation**

Costs (USD/ha) [year(s) of occurrence]		**Revenues (USD/ha)** [year(s) of occurrence]	
Planting [year 0]	506	Intercrop (cassava) sales [years 0–2]	298
Replacement planting [year 1]	218	Timber sales [year 14]	3 000
Maintenance [year 2]	88		
Maintenance [years 3–5]	30		
Timber harvesting and transportation [year 14]	600		

- Option 2: Agricultural crop (maize) production. Table 19 shows the costs and revenues associated with this option.

TABLE 19. **Hypothetical costs and revenues associated with maize production**

Costs (USD/ha) [occurrence: annual]		**Revenues (USD/ha)** [occurrence: annual]	
Seeds	95.90	Maize sales	1 445
Fertilizers	399.60		
Herbicides and pesticides	73.40		
Labour	522.70		

In both cases, the area is assumed to be 1 ha, and two discount rates (7 percent and 9 percent) are used. Use the CBA tool in Annex 4 to estimate the benefit–cost ratios for both options.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Module 6 | Regulating services

KEY MESSAGES

- The main forest-based regulating ESs in Bangladesh are protection against storms and tidal surges (especially the protection provided by mangroves and other coastal forests), flood control, and carbon sequestration.
- Various methods can be used to value regulating ESs. The most common are those using market values, including direct market values (e.g. for carbon), production function (e.g. the pollination benefits of forests or the influence on off-shore fisheries of mangroves and coastal wetlands), and methods adopting costs as a proxy (e.g. replacement cost and cost of substitute goods). Demand-curve approaches, particularly direct methods (stated preferences) such as contingent valuation and choice modelling, can also be used but are generally more data- and resource-demanding.
- This module provides examples of valuations of carbon sequestration (market-value method) and of ESs that provide protection in coastal areas against storms and tidal surges (replacement cost, avoided costs for defensive expenditures, and cost of substitute goods).

Regulating ESs are processes that improve the physical environment for certain human purposes, such as through their influence on the atmosphere, water resources, soils and pests, thus having economic significance (Price, 2014). Table 20 shows some key forest-based regulating ESs in Bangladesh, as reported by Barua, Boscolo and Animon (2017) based on available literature.

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TABLE 20. **Main forest-based regulating and maintenance ecosystem services in Bangladesh, by forest zone**

Ecosystem service	Forest zone				
	Sundarbans	Coastal	Village	Sal	Hill
Mediation of waste, toxic substances and other nuisances	Nutrient cycling [*]	*None reported*	Nutrient cycling [*]	Nutrient cycling [*]	Nutrient cycling [**]
Mediation of flows	Protection from sea storms and tidal surges [***] Stabilization of newly accreted land [**] Control of salinity intrusion [**]	Protection from sea storms and tidal surges [***] Stabilization of newly accreted land [***] Control of salinity intrusion [**]	Soil erosion control [*]	Soil erosion control [*]	Soil erosion control [***] Watershed regulation [***]
Maintenance of physical, chemical and biological conditions	Biodiversity conservation [***] Carbon sequestration [***]	Carbon sequestration [**] Biodiversity conservation [*]	Carbon sequestration [***] Pollination [**] Biodiversity conservation [**]	Carbon sequestration [***]	Carbon sequestration [**] Pollination [**] Biodiversity conservation [**]

Notes: Level of importance: * = low; ** = medium; *** = high.
Source: Barua, Boscolo and Animon (2017).

6.1 AVAILABLE METHODS

The value of regulating ESs can be estimated using various methods. According to the literature, the most commonly applied methods for valuating regulating ESs involve available market prices and costs as proxy (Pascual and Muradian, 2010; Brouwer *et al.*, 2013).

Market values

Carbon sequestration is among the most studied regulating ESs and one of the most important ESs in Bangladesh. Petrokofsky *et al.* (2012) conducted a systematic review of methods for measuring and assessing carbon stocks and carbon-stock changes in terrestrial carbon pools. The online platform Global Forest Watch Climate provides national and subnational estimates of aboveground biomass, belowground biomass and soil carbon.[59]

Valuations of forest-based carbon sequestration services can take advantage of the dynamic international market for carbon credits (Hamrick and Gallant, 2017). Valuations should be built on the quantification of the carbon sequestration capacity of a given forest area in one or more of the five carbon pools[60] using appropriate scientific approaches.

[59] http://climate.globalforestwatch.org. See Harris (2016) for insight into how the platform works.

The International Panel on Climate Change provides technical guidance on quantifying carbon sequestration in forests (IPCC, 2006). Additional guidance, tools, software and examples for assessing the volume, biomass and carbon stock of trees and forests are available on the GlobalAllomeTree website.[61] Carbon prices (per tonne of carbon dioxide-equivalent) can be obtained from existing markets[62] using tools such as those available on Forest Trend's Ecosystem Marketplace website (see the Market Watch tool[63] and the annual State of Forest Carbon Markets reports[64]).

Markets are also used indirectly when the **production function method** is used to value regulating ESs based on the principle that "marketable benefits are created or lost elsewhere in the economy through ecosystem services" (Price, 2014). The most crucial aspect in this case is an understanding of the biophysical (as well as human-induced) processes that regulate the production of marketable benefits and the role of the regulating ESs under analysis. Sometimes it may not be possible to isolate the effects of ESs, and the application of models and functions requires specific skills and expertise. Table 21 provides examples.

TABLE 21. **Examples of production function applications**

Ecosystem service considered as an input	Market good considered as an output	Description and examples
Pollination by insects	Agricultural crops	Planted and natural forests provide habitat for pollinators serving nearby agricultural areas. The value of the pollination service is reflected in an increase in the net cash yield of crops. Example: Partap *et al.* (2012) estimated that the total economic value of insect pollination for selected crops in the Hindu Kush Himalayan region (comprising the Chittagong Hill Tracts of Bangladesh; Bhutan; the Chinese Himalayan provinces; Himachal Pradesh and Kashmir in the northwestern Indian Himalayas; Uttarakhand in the Central Indian Himalayas; and the Himalayan region of Pakistan) at nearly USD 2.7 billion/year. The value in the Chittagong Hill Tracts (Bandarban, Rangamati and Khagrachari districts) was estimated at USD 53.8 million/year. Additional useful references: Gallai and Vaissière (2009); FAO (2006); Klein *et al.* (2007); Winfree, Gross and Kremen (2011)

Table 21 continues on next page

60 The five carbon pools are aboveground biomass, belowground biomass, soil and litter, deadwood, and harvested wood products.

61 www.globallometree.org

62 It should be borne in mind, however, that market prices for carbon credits might differ from the social cost of carbon, which monetizes the actual damage caused by emitting carbon dioxide or its equivalent. More precisely, the social cost of carbon is the change in the discounted value of economic welfare caused by an additional unit of carbon dioxide-equivalent emissions (Nordhaus, 2017).

63 www.ecosystemmarketplace.com/marketwatch

64 www.ecosystemmarketplace.com/publications/?category=forest-carbon

Table 21 continued

Ecosystem service considered as an input	Market good considered as an output	Description and examples
Maintenance of nursery populations and habitat conditions by coastal (or wetland) ecosystems (e.g. mangroves)	Offshore fisheries	The conservation of coastal vegetation (e.g. mangrove forests) can provide spawning grounds and nurseries for fry, thus enabling the growth of fish stocks (and helping ensure fish harvesting levels). Example: Lynne, Conroy and Prochaska (1981) estimated that the annual per-ha contribution of mangroves to total Indian marine fish production was 1.86 tonnes. This corresponds to a total annual production of 8.67 million tonnes (i.e. 23 percent of the total national fish production in India), valued at about USD 1.13 billion
Groundwater and surface water for non-human use	Agricultural crops Timber production	Natural ecosystems can facilitate the availability of groundwater and surface water that can be used as an input to agricultural and forest management activities downstream. Changes in the availability of water are reflected in variations in output quantities and value. Example: DSS Management Consultants (2010) estimated that a 50 percent reduction in water supply would result in an annual loss in the value of the Canadian wood harvest of about USD 375 million

Costs as proxy

Despite the limitations outlined in module 4 (see, in particular, section 4.1), the costs-as-proxy method is commonly used in valuations of regulating ESs. Most regulating ESs lack direct market value but they have indirect links because they can be substituted or surrogated by human-made infrastructure or interventions. Alternatively, it may be possible to restore or reproduce ecosystems that supply such ESs. Barbier (2016) reviewed valuation studies on the protection services provided by mangrove ecosystems. Narayan *et al.* (2016) analysed the effectiveness and costs of various coastal nature-based defence systems through a meta-analysis of about 70 studies at the global scale. In Viet Nam, for example, they found that, for the same level of protection (as indicated by wave height reduction), mangrove restoration projects could be 3–5 times cheaper than building a submerged breakwater. This indicates that nature-based solutions that take advantage of ESs can be effective and economically viable solutions, although it might also suggest that costs-as-proxy approaches could overestimate ESs.

Defensive expenditures can be used in costs-as-proxy methods to estimate regulating ESs such as protection against natural risks (e.g. floods, landslides, water and soil salinization, and tidal surges). According to Price (2014), the avoided cost of defensive expenditures is the most widely used approach for valuing regulating ESs. The rationale for this approach is that, without regulating ESs, outlays would be needed either to achieve equivalent protection or to remedy the consequences of a lack of protection. Commonly, this method uses a "with/without" approach, projecting how the situation would evolve over time in the presence of ecosystem management and conservation measures (e.g. coastal forest restoration and maintenance) and in their absence (i.e. the progressive deterioration of the ecosystem). Ecosystems are thought of as producing services (e.g. the protection of economic activity, property and human lives) that benefit individuals by limiting damage. This method is also called the "expected damage function" approach and can be seen as an adaptation of the production function method (Barbier, 2016).

Table 22 presents a comparison of the estimated welfare impacts of the loss of the storm protection service due to mangrove deforestation in Thailand, computed through the expected damage function approach and the cost of substitute goods. The latter approach tends to provide much higher estimates and, although it is simple and relatively low-cost, it should therefore be used with caution. The expected damage function approach has limitations, too, especially when people are risk-averse, in which case the approach may poorly catch the *ex-ante* WTP to reduce or avoid the risk of damage from storms or other hazards.

TABLE 22. **Estimated welfare impacts of the loss of the storm-protection ecosystem service as a result of mangrove deforestation in Thailand (1996–2004)**

	Estimated welfare impact (USD)	
	Deforestation rate of 18 km^2 per year*	Deforestation rate of 3.44 km^2 per year**
Cost of substitute goods		
Annual welfare loss	25 504 821	4 869 720
NPV (r = 10%)	146 882 870	28 044 836
NPV (r = 12%)	135 896 056	25 947 087
NPV (r = 15%)	121 698 392	23 236 280
Expected damage function approach		
Annual welfare loss	3 382 169	645 769
NPV (r = 10%)	19 477 994	3 718 998
NPV (r = 12%)	18 021 043	3 440 818
NPV (r = 15%)	16 138 305	3 081 340

Notes: * = estimate by FAO; ** = estimate by Royal Forestry Department, Thailand. NPV = net present value; r = discount rate.
Source: Barbier (2016).

Contingent valuation, choice modelling and benefit transfer

When it is crucial to obtain reliable estimates of ESs and knowledge of how they will be affected by a given intervention (e.g. a large infrastructure project), regulating ESs can be valued using demand-curve approaches such as contingent valuation and choice modelling (assuming the availability of sufficient time and resources). These methods estimate people's WTP for ESs. Christie *et al.* (2007), for example, assessed the value of various biodiversity conservation policies in the United Kingdom of Great Britain and Northern Ireland through a choice-modelling exercise using five attributes, including the provision of regulating ESs like flood protection.

In the absence of sufficient resources and expertise, approaches that produce quicker and simpler results may be preferred. In deciding which method to employ, the aim of the study, technical, budgetary and time constraints, the quality and availability of existing data, and the spatial scale should all be considered, in close consultation with the expected users of the findings.

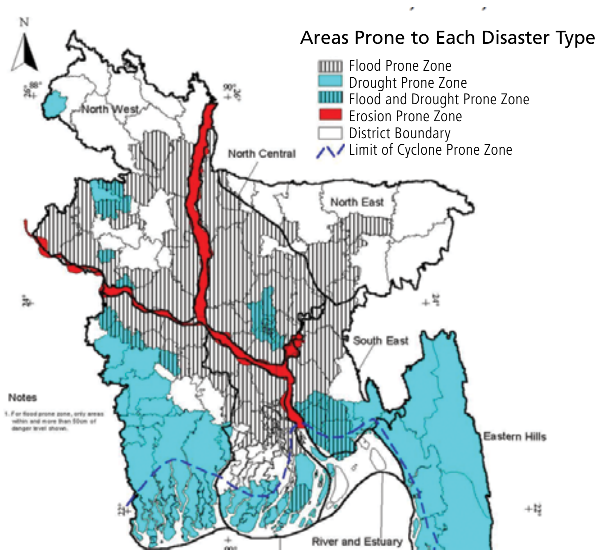
6.2 EXAMPLES

Two examples of valuations of forest-based regulating ESs in Bangladesh are described below.

Coastal protection against storms and tidal surges

Bangladesh is highly prone to floods, cyclones and storm surges because of its location in the delta formed by the Ganges, Brahmaputra and Meghna rivers, its low-lying character (two-thirds of the country is less than 5 m above sea level) and, in certain coastal areas, its high population density, precipitation patterns, and the general conditions of its coastal protection system (Habib, Shahidullah and Ahmed, 2012) (Figure 35). On average, a severe cyclone makes landfall on the Bangladesh coastline once every three years, either before or after the monsoon, creating storm surges that can be in excess of 10 m (World Bank, 2010). The risk of storms and storm surges is likely to increase in the future in the face of climate change.

FIGURE 35
Areas prone to various natural disasters in Bangladesh



Source: Mallick, Amin and Rahman (2012).

The World Bank (2010) estimated that the average direct annual costs of natural disasters to the national economy (i.e. damage to infrastructure and livelihoods and losses in foregone production) are in the range of 0.5–1 percent of GDP. The average economic loss due to a severe cyclone in Bangladesh is estimated at USD 1 802 million, which is about 2.4 percent of GDP. This estimate does not include loss of life: despite declining cyclone-related mortality, more than 700 000 people have died due to cyclones in Bangladesh in the last 50 years (Haque *et al.*, 2012).

Source: Mallick, Amin and Rahman (2012).

Bangladesh's entire coastline is at risk to cyclones and the storm surges they induce. Defensive measures to mitigate climate change and the expected increase in storm intensity involve both green and grey infrastructure (McCreless and Beck, 2016). The former includes the conservation or restoration of coastal habitats, including through afforestation, which can play crucial roles and which have received increased attention in recent decades (Narayan *et al.*, 2016). There is considerable scientific evidence that mangrove forests can provide coastal protection against storms and floods, mainly through their ability to attenuate waves and buffer winds (Barbier, 2016). In Bangladesh, this protection was evident in the 1991, 2007 (Sidr) and 2009 (Aila) cyclones. In 1991, for example, there was extensive damage to property and loss of life where mangrove forests were absent (World Bank, 2010); on the other hand, storm surge velocity was cut where coastal vegetation was present on the foreshores of embankments, thus reducing damage and loss of life (Mahmud and Barbier, 2014).

Experts from several national institutions in Bangladesh, including the Department of Forests, have recommended planting a mangrove forest belt with a minimum width of 500 m to protect the embankments of sea-facing polders. Where significant livelihoods and assets are at risk, coastal afforestation may be a cost-effective method for protecting sea-facing polders from above-average severe storms. Although it may not strictly be needed to protect against average 10-year return-period cyclones, afforestation would provide essential and cost-effective protection against more intense cyclones.

What is the value of such protection from sea storms and tidal surges? Various methods can be used to produce quick estimates.

The replacement-cost approach

Presently, mangrove forests protect about 60 km of the total 957 km of embankments along sea-facing polders (World Bank, 2010), meaning that 897 km of coastline still needs protection. Assuming that a forest belt 0.5 km (i.e. 500 m) wide is to be created, the total area to be afforested would be 448.5 km^2 (44 850 ha). Based on data from the Institute of Water Management and DHI (2000), the World Bank (2010) reported average afforestation costs of USD 168 000/km^2. Therefore, the total cost of afforestation to reduce the hydraulic load on embankments would be USD 75 million, or about USD 1 672/ha.

Using avoided costs for defensive expenditure

It has been estimated that afforestation of a 500-m-wide coastal belt could reduce the need to increase embankment height by up to 30 cm (Institute of Water Management and DHI, 2000). The World Bank (2010) identified those coastal polders needing height increases to prevent overtopping both in current conditions (30 polders) and under the expected impacts of climate change (33 polders) and estimated both the increases in height needed and the costs involved. If afforestation with mangroves reduces the increase in embankment height by 30 cm (Table 23), the **total avoided costs for defensive expenditures** would be USD 153.76 million (USD 3 428/ha) for current conditions and USD 168.14 million (USD 3 749/ha) under projected climate change.

TABLE 23. **Estimated cost of height increases for coastal polders to prevent overtopping**

Enhancement measure	Baseline (current condition)	Climate change
No. of enhanced coastal polders	30	33
Total height increase (m)	114.80	169.85
Cost of enhancement (million USD/m)	18.68	15.53
Total avoided enhancement due to afforestation (0.3 x no. of enhanced polders) (m)	9	9.9
Total avoided costs for defensive expenditure (USD million)	168.14	153.76

Source: Modified from World Bank (2010).

Substitute-cost approach

The **substitute-cost approach** can be used to estimate the value of protection from sea storms and tidal surges by forests by assuming that grey infrastructure such as seawalls and dykes can be built as alternatives (or complements) to green infrastructure. Based on available literature, the average construction cost of 1 m of a 3.5-m-high concrete dyke is estimated at USD 950 (Lenk *et al.*, 2017). Given that 897 km of embankments on sea-facing polders need protection, the total substitution cost would be *950 × 897 000 = USD 852 million* (about USD 18 996/ha). This is about eight times more than the cost of afforestation, which is in line with estimates in other studies (Tallis *et al.*, 2008). It is important to stress, however, that the substitute-cost approach should be used with caution to estimate the value of ESs such as storm protection (Barbier, 2016) because it essentially means estimating a benefit (e.g. storm protection) using a cost (e.g. the costs of constructing seawalls, breakwaters and dykes). Human-built alternatives are rarely the most cost-effective way of providing a protection service (Barbier, 2007; Freeman, Herriges and Kling, 2014), and grey infrastructure does not normally provide additional ESs (such as carbon sequestration and biodiversity conservation).

Carbon sequestration

About 12 percent of the land area of Bangladesh is hilly. In the Chittagong district in the country's southeast, where 51 percent of the land area is hilly, 150 000 ha of hilly land is degraded in the Hathazari-Fatikchari and Raozan-Rangunia ranges. This land has been deforested in the last 50 years and is now mostly covered by sungrass (*Imperata cylindrica*), shrubs, creepers, vines and scattered trees (Barua and Haque, 2013).

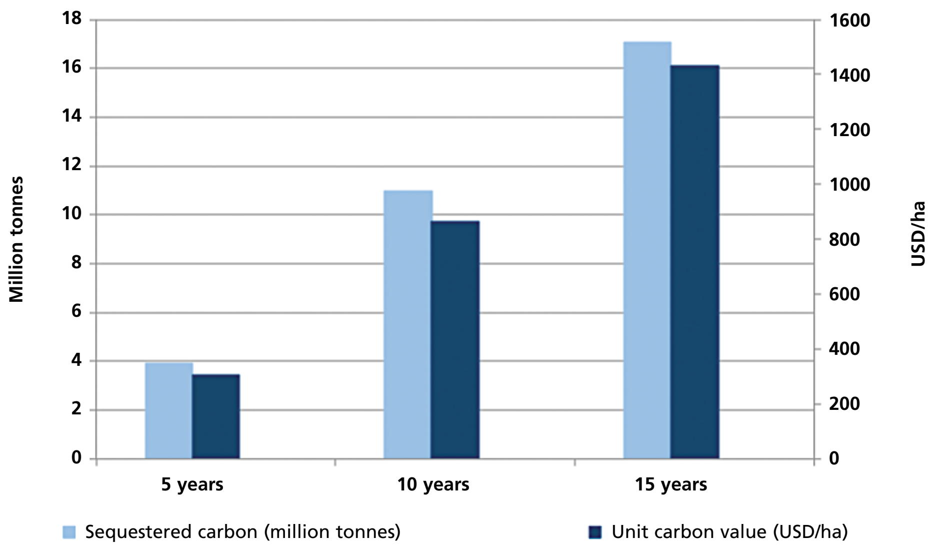
Barua and Haque (2013) estimated the carbon sequestration that could be achieved by planting trees on this land, and its economic value. Two scenarios were examined:

1. BAU – do nothing new; and
2. plantation – plant the degraded land with acacia on a rotation of 15 years.

It was assumed that the sequestered carbon would be sold in voluntary international carbon markets as temporary carbon credits. The credits would be issued and paid for at the end of each 5-year period – that is, in years 5, 10 and 15. The credits expiring in year 5 would be added to those generated in years 6–10, and those expiring in year 10 would be added to those generated in years 11–15. The NPV approach was used in the valuation of carbon sequestration for one rotation period of 15 years.

It was estimated that an acacia plantation in degraded hills in the Chittagong district would sequester more than 17 million tonnes of carbon over a 15-year rotation. At a carbon price of USD 18 per tonne[65] (USD 4.9 per tonne of carbon dioxide), the value of sequestration would be USD 1 430/ha (Figure 36) and about USD 215 million for the entire 150 000 ha of plantations (Figure 37) over the rotation period. The carbon value is sensitive to price, as shown in Figure 38, and to the market interest rate.

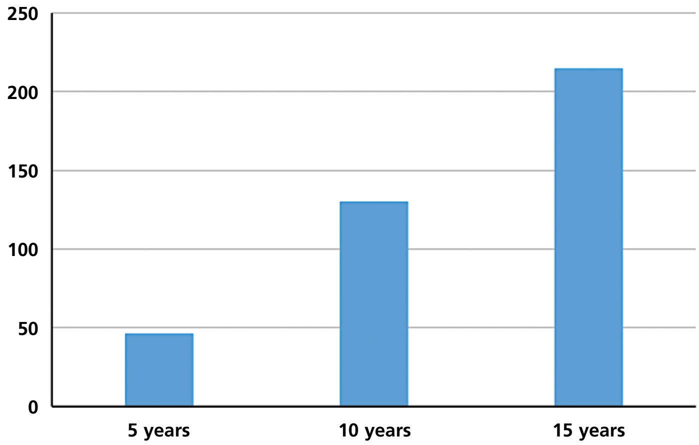
FIGURE 36
Sequestered carbon and unit carbon value in acacia plantations in degraded hills in Chittagong, Bangladesh



Source: Modified from Barua and Haque (2013).

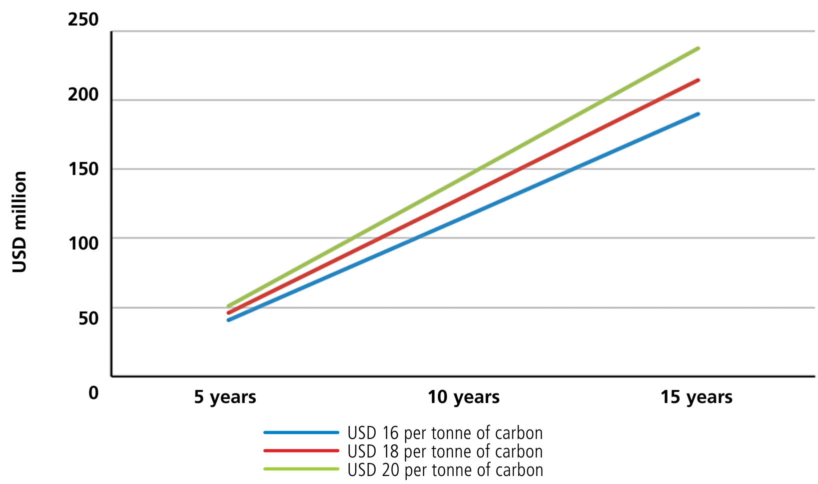
[65] This was the price in the international carbon market in 2010 when the study was performed (Barua and Haque, 2013).

FIGURE 37
Total net present value of carbon sequestered in tree plantations in degraded hills in the Chittagong district, Bangladesh



Source: Barua and Haque (2013).

FIGURE 38
Sensitivity analysis of the total net present value for three prices per tonne of carbon



Source: Barua and Haque (2013).

Exercise 12 analyses potential trade-offs between aquaculture development and mangrove restoration for the provision of multiple ESs, including regulating ones, in coastal areas.

Exercise 12. Trade-offs between aquaculture development and mangrove restoration

In the last 15–20 years, a 150-ha area of mangrove forest has been degraded as a result of policies that encouraged the conversion of coastal forests to aquaculture and the expansion of urban areas and related infrastructure (e.g. roads and dykes). Urbanization poses an ongoing risk to the remaining mangrove forests. The local communities are vulnerable to climate change, particularly in low-lying areas, which are prone to flooding, storm surges and coastal erosion.

By performing a cost–benefit analysis (at a discount rate of 10 percent over a period of 20 years), assess the relative desirability of the following two options:

1. aquaculture development; and
2. mangrove restoration.

Option 1: aquaculture development

Table 24 shows the estimated costs and revenues for aquaculture development (option 1), as obtained from local aquaculture businesses.

TABLE 24. **Costs and revenues for aquaculture development**

Costs (USD/ha) [occurrence: annual]		**Revenues (USD/ha)** [occurrence: annual]	
Pond preparation	1 080	Fish sales	2 886
Breeding	480		
Industrial feed	172		
Fresh feed	440		
Labour	272		
Materials for ponds (lime, medicine)	50		

Option 2: mangrove restoration

Table 25 shows the costs of mangrove restoration, as obtained from nearby restoration projects with similar ecological and socio-economic conditions. Local experts have confirmed the data. The benefits of mangrove restoration have been estimated in a contingent valuation exercise involving local communities. In this option, no harvesting or collection activities will be allowed in the reforested area for 20 years.

TABLE 25. **Costs and revenues for mangrove restoration**

Costs (USD/ha) [year(s) of occurrence]		**Revenues (USD/ha) [year(s) of occurrence]**	
Restoration [years 0–3]	952	Support to fishing [years 2–19]	350
Maintenance and surveillance [years 0–3]	53	Shoreline stabilization [years 3–19]	350
Maintenance and surveillance [years 4–19]	40	Coastal protection [years 5–19]	3 200

Exercise 13 assesses potential trade-offs in ESs under different development scenarios and land uses.

Exercise 13. **Assessing trade-offs in ecosystem services among different scenarios**

Consider the following two cases: 1) coastal afforestation and rice-cropping; and 2) village forestry. For each case, perform a cost–benefit analysis (CBA) (at a discount rate of 10 percent over a period of 20 years) to inform decision makers of the most desirable scenario.

1. Coastal afforestation and rice-growing

The following conditions need to be taken into account in planning the management of, and investments in, 20 000 ha of coastal land over the next 20 years. Given the increasing risk of cyclones and other storms, coastal and adjoining areas need protection. In providing defence against storms and tidal surges, coastal afforestation can also generate additional benefits, such as carbon sequestration, the formation and stabilization of new land suitable for future agriculture, and increased biodiversity. Based on surveys it is clear that the local community is worried about the increasing risk posed by storms and wants specific prevention or mitigation measures taken.

Alternatively, the same land could be used for agriculture. In particular, rice can be grown easily, and two crops per year are feasible – although, because of increasing soil salinity, salinity-resistant varieties must be used. Local farmers are strongly dependent on rice production for income; increased production could help increase food security at the local and wider scales.

A – Coastal afforestation

Under the planned afforestation programme, 1 000 ha will be planted per year for 20 years. Woodlots will produce 5 m^3/ha of woodfuel per year, five years after planting. The area not used for woodlot plantations will be used for growing rice (two harvests per year, 5 tonnes/ha per year at 2.5 tonnes/ha per harvest). Table 26 provides additional data.

TABLE 26. **Costs and benefits of coastal reforestation**

Costs (for 1 ha)*

Input		Unit cost
Item	**Total needed**	
Labour (planting)	30 days	BDT 500 per day
Seedlings	2 500 seedlings	BDT 20 per seedling
Labour (maintenance)	10 days	BDT 500 per day
Machinery	5 days	BDT 2 500 per day

Exercise 13 continues on next page

Exercise 13 continued

Benefits

Benefit		Notes
Item	Value	
Coastal protection	BDT 650 000/ha per year	Accrues ever year, 5 years after planting
Woodfuel	BDT 650 per m^3	5 m^3/ha per year, 5 years after planting

* See Table 27 for costs associated with rice-growing.

B – Rice-growing

In this option, the entire area would be dedicated to rice-growing for 20 years. Costs include labour, seeds (of salinity-tolerant varieties), irrigation, chemical inputs (pesticides and fertilizers) and machinery. The favourable conditions are expected to enable two crops per year. The expected yield is 2.5 tonnes/ha per harvest. Table 27 provides additional data.

TABLE 27. **Costs and benefits of rice-growing**

Costs (for 1 ha)

Input		Unit cost
Item	Total needed (per year)	
Labour (amount)	100 days	BDT 500 per day
Seeds (cost)	BDT 6 000	BDT 200 per harvest
Irrigation (cost)	BDT 20 000	BDT 10 000 per harvest
Chemical inputs (cost)	BDT 30 000	BDT 15 000 per harvest
Machinery (cost)	BDT 10 000	BDT 5 000 per harvest

Benefits

Benefit		Notes
Item	Value	
Rice	BDT 25 000 per tonne	Two harvests per year, 5 tonnes/ha per year

In the absence of information on the market value of honey and wax, their value could also be estimated based on the access fees paid by harvesters. A BLC costs BDT 7 000 and one boat carries 7–9 people, equating to a BLC cost per person (harvester) of BDT 777–1 000 (USD 10–13). If the annual harvest of honey and wax in the Sundarbans amounts to 128 tonnes, and each harvester collects up to 75 kg, there would be 1 707 harvesters. This would generate total access and harvesting fees in the range of BDT 1.3–1.7 million (USD 17 000–22 000) per year, not counting informal/illegal harvesting.

Exercise 13 continues on next page

Exercise 13 continued

Case 2: Village forestry

There are 268 000 ha of village forests in Bangladesh. For many communities, these are the main sources of timber and woodfuel, which are sold in local markets and, in the case of woodfuel, partly consumed in the villages themselves. At the same time, growing concern about climate change and the increasing role of the carbon sector are leading to calls for measures aimed at increasing carbon sequestration in natural ecosystems.

Scenario A – Timber and woodfuel production

Village forests can be managed for timber and woodfuel by extracting, each year, a volume that does not exceed the mean annual increment, which is estimated at 11 m^3/ha. The total annual harvest is estimated to comprise 40 percent timber and 60 percent woodfuel. Both timber and woodfuel are sold in the local markets, although part of the woodfuel is used for self-consumption. Crops (vegetables) are grown under tree canopies and benefit from wood-harvesting operations through increased light and solar radiation. The value of the vegetable crop is estimated at BDT 7 440/ha per year. Table 28 provides additional data.

TABLE 28. **Costs and benefits of village forests**

Costs (for managing and harvesting 1 ha)

	Unit cost (BDT per day)	Total needed
Labour	500	25 days
Equipment (new)	5 000	New equipment bought every 4 years
Equipment (maintenance)	500	-

Benefits

	Unit value	Notes
Timber	BDT 17 000/m^3	40% of total volume
Woodfuel	BDT 650/m^3	60% of total volume
Crops	BDT 7 440/ha per year	Vegetables

Scenario B – Carbon sequestration

In this option, the area will be subject to forest management according to standards that ensure the production of carbon credits. This includes a forest inventory (mostly taking advantage of the national forest inventory and using satellite imagery) and the formulation and implementation of a forest management plan. The wood-harvesting rate will be dramatically less than in scenario A because harvesting will be limited to thinning and pruning operations performed every five years. Crops will be grown under the tree canopy in this scenario, but the yield will decline by 40 percent compared with scenario A due to the lower availability of solar radiation. Table 29 provides additional data.

Exercise 13 continues on next page

Exercise 13 continued

TABLE 29. **Costs and benefits of carbon sequestration**

Costs

	Unit cost	Notes
Inventory	BDT 4 000/ha	268 000 ha
Management plan	BDT 1 000/ha	268 000 ha
Labour	BDT 500 per day	10 days/ha
Equipment (new)	BDT 5 000/ha	Purchased at year 0
Equipment (maintenance)	BDT 500/ha per year	Cost incurred once every 5 years

Benefit

	Unit cost	Notes
Carbon	BDT 240 per tonne of carbon-dioxide equivalent	USD 3 per tonne of carbon-dioxide equivalent
Timber	BDT 17 000/m3	40% of total volume
Woodfuel	BDT 650/m^3	60% of total volume
Crops	BDT 7 440/ha per year	Vegetables

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Module 7 | Cultural services

KEY MESSAGES

- The main forest-based cultural ESs in Bangladesh are the provision of tourism and recreation opportunities, wilderness, and the symbolic value of flagship species (especially the Royal Bengal tiger).
- Cultural ESs are usually valued using demand-curve approaches. Tourism and recreation services are the most studied of the cultural ESs. Multiple approaches can be used for valuation, but the most commonly used is the travel-cost method – valuing the direct-use value of the recreational service offered by a site. Contingent valuation and choice experiments can be used to value some cultural ESs, such as the symbolic value of wild species (e.g. the Royal Bengal tiger). Hedonic pricing can be used to capture the value of environmental attributes (e.g. landscape amenity and general environmental quality) reflected in the market value of certain goods (e.g. house prices).
- Examples are provided for valuing tourism and recreation (using the travel-cost method) and the symbolic value of species (contingent valuation).

Cultural ESs are the non-material benefits people obtain from ecosystems through, for example, spiritual enrichment, cognitive development and recreation (DEFRA, 2007). They can be defined as "sensory experiences of the ecosystem that enhance human well-being aesthetically and spiritually" (Price, 2014). The economic value of cultural ESs comprises both non-consumptive use values (e.g. in the case of tourism and recreation, and education and research) and passive-use values (e.g. in the case of the symbolic value attributed to certain species and the spiritual or religious value of certain species or sites). Table 30 summarizes the main forest-based cultural ESs in Bangladesh reported in Barua, Boscolo and Animon (2017) based on available literature.

TABLE 30. **Main forest-based cultural ecosystem services in Bangladesh, by forest type**

Section	Division	Forest types in Bangladesh				
		Sundarbans	Coastal	Village	Sal	Hill
Cultural	Physical and intellectual interactions with biota, ecosystems and landscapes	Tourism [**] Education and research [**] Cultural heritage value [**]	Education and research [**] Tourism [*]	Education and research [**]	Tourism [**] Education and research [*]	Tourism [**] Education and research [**]
	Spiritual, symbolic and other interactions with biota, ecosystems and landscapes	Symbolic value of tigers [***] Wilderness [**]	Wilderness [**]	Wilderness and bequest values [**]	Wilderness [*]	Wilderness [*]

Level of importance: * = low; ** = medium; *** = high.
Source: Barua, Boscolo and Animon (2017).

7.1 AVAILABLE METHODS

Cultural ESs are usually valued using demand-curve approaches; tourism and recreation are probably the most studied. The travel-cost method is mostly used to assess the direct-use value of a site, such as a park or forest, by accounting for the direct and indirect costs borne by visitors.

As reported in section 7.2, a number of studies have been carried out in Bangladesh, mostly according to the zonal travel-cost method (see section 4.2). A common gap in many of these studies, however, is that they do not consider positive and negative variations in travel cost. Such consideration is needed to construct the demand curve and calculate the total consumer surplus (and hence the WTP) in site visitation. Many studies in Bangladesh address the issue of additional costs simply by asking respondents to indicate their WTP for a higher entrance fee. The analysis of variations in the number of trips due to variations in travel cost is a crucial step in this method because, in addition to enabling calculation of the consumer surplus, it provides other information useful for decision making. For example, it can help in setting entrance fees that optimize the number of visitors to a site and the revenues earned – which can be reinvested to improve the area and the services it offers.

The **travel-cost method** is suitable for estimating the economic benefits and costs arising from (hypothetical or real) changes in access costs to a site (e.g. to set entrance fees or develop logistics for the site); the elimination of an existing recreational site or the creation of a new site; and changes in the environmental quality of a recreational site (e.g. expansion, new management regimes and new facilities). The travel-cost method is based on actual behaviour and can be explained readily to decision makers and the public. The travel-cost method comes with a number of caveats and limitations, however (see section 4.2), which should be taken fully into account. Problems may arise, for example, in dealing with multiple trip destinations, substitute sites, and situations in which all visitors bear similar costs (e.g. urban parks).

Other demand-curve approaches can be used for valuing recreation and tourism ESs, which might produce more precise estimates for specific characteristics of a site and capture passive-use values. Other approaches, however, are usually considerably more complicated and expensive to apply than the travel-cost method.

Contingent valuation and choice modelling can be used to value other types of cultural ESs and to estimate passive-use values. Notwithstanding the limitations highlighted in section 4.3 (for example, both these methods are highly time- and resource-consuming and require considerable econometric skills), these methods have huge potential for ES valuation – which seems to be confirmed by the increasing number of studies and applications in which these methods are used. Section 7.2 presents an application of contingent valuation in the estimation of passive-use cultural ESs in Bangladesh.

Hedonic pricing can be used to value cultural ESs such as landscape amenity and environmental quality. As mentioned in section 4.2, however, this method is very demanding in terms of data quality and quantity, and it requires specific econometric skills and expertise. The method relies on the linkage between variation in a certain ES (or environmental attribute) and the market price of a good. The most common application in the literature is in the influence of local environmental attributes on house prices. It requires, therefore, an active housing market, access to reliable data, and a clear perception in a population of the link between environmental attributes and quality of life (thereby leading to higher property prices in locations with pleasant environments). This method might be problematic, therefore, in rural Bangladesh, but it might be applicable in periurban and urban areas close to tourism sites where environmental attributes are important factors in attracting visitors. It should be noted that the hedonic-pricing approach can be used for other purposes (see Box 26).

BOX 26

An analysis of catfish prices in Bangladesh using hedonic pricing

Khan (2012) used a hedonic model to estimate variations in the price of catfish (*Pangasius* spp.) due to quality attributes in a domestic market in the Barishal district (southern Bangladesh). The model used both continuous variables (catfish weight and standard length) and dummy variables that represented qualitative attributes such as freshness (gill colour), origin of product, time of day (morning or evening), day factors (weekday or weekend), and marketing and transportation costs (captured in the mode of sale and type of fish preservation).

Results show that catfish price and continuous variables are strongly correlated: in particular, a significant increase in price was observed with increasing fish weight. Of the dummy variables, local origin had little influence on price (high-quality *Pangasius* is mostly produced in intensive and semi-intensive aquaculture plants in Mymensingh in northern Bangladesh), and day factors were also unimportant. Higher influence was detected for freshness (a price premium of up to USD 0.15/kg), time of day (with higher prices identified in the morning, with a price premium of up to USD 0.04/kg), and preservation method (there was a relatively high correlation between price and conservation with ice, which is generally associated with greater freshness).

7.2 EXAMPLES

Two examples of forest-based cultural ESs relevant for Bangladesh are tourism and recreation, and the symbolic and cultural value of species, discussed further below.

Tourism and recreation

The travel-and-tourism sector contributed about 4 percent of the Bangladesh GDP in 2014, and this contribution is expected to grow to 6.5 percent by 2025. Spending on domestic travel generated about 98 percent of the contribution of the travel-and-tourism sector, and foreign visitors accounted for the remaining 2 percent (WTTC, 2015). At the global level, increasing demand for green or “slow” recreation and tourism means that natural and protected areas are increasingly important factors for tourists and other visitors (Arnberger *et al*., 2012; Mayer *et al*., 2010). Ecotourism[66] has become an integral part of sustainable tourism, which is tourism that makes "optimal use of environmental resources that constitute a key element in tourism development, maintaining essential ecological processes and helping to conserve natural heritage and biodiversity" (UNEP and WTO, 2005). The United Nations designated 2017 as the International Year of Sustainable Tourism for Development.[67]

Alam, Furukawa and Akte (2009) listed potential ecotourism opportunities in Bangladesh and identified impediments to the expansion of the ecotourism industry, including forest degradation and conflict among the stakeholders. Tourism is not fully developed in Bangladesh, but it is growing. Uddin *et al.* (2013), for example, reported that the number of visitors to the Sundarbans doubled between 2000 and 2010, and there was a fourfold increase in the revenues collected from them. This growth was driven mostly by international tourists, the number of whom increased fivefold in the period. This trend suggests that there is huge potential to increase tourism in the Sundarbans (Islam, Hossain and Noor, 2017).

Most studies analysing and valuing the tourism and recreational value of natural areas in Bangladesh have used the travel-cost method. Table 31 provides examples of these.

TABLE 31. **Examples of economic valuations of tourism and recreation ecosystem services in Bangladesh**

Author/s (year)	Method	Study area/site	Findings
Shammin (1999)	Zonal travel cost	Dhaka Zoological Garden	Individual willingness to pay (WTP): USD 3.91/day Without opportunity cost of time: USD 3.48/day Total WTP: USD 16.77 million per year
Rahman (2013)	Individual travel cost	Patenga Beach	Maximum WTP for entrance fee: USD 1.30 Total travel cost per person: USD 6.18
Bashar (2015)	Zonal travel cost	Sundarbans Forest Reserve	Total asset value: USD 2.56 million per year WTP for entrance fee: USD 0.65
Kawsar *et al.* (2015)	Zonal travel cost	Lawachara National Park	Total travel cost per person: USD 3.66 Total asset value: USD 0.72 million per year
Islam and Majumder (2015)	Zonal travel cost	Foy's Lake (Chittagong)	Total asset value: USD 3.92 million per year

Uddin *et al.* (2013) estimated the economic value of tourism in the Sundarbans in terms of the revenue collected from tourists (USD 42 000 per year, on average, in 2000–2010). Islam and Dooty (2015) estimated the WTP of visitors for several nature-based tourism sites

[66] Ecotourism is environmentally responsible travel and visitation to relatively undisturbed natural areas in order to enjoy and appreciate nature that promotes conservation, has low visitor impact and provides for beneficially active socio-economic involvement of local populations (IUCN, 2002).

[67] www.tourism4development2017.org

in Sreemangal-Kamalganj (in the northeast of Bangladesh). Using a "spurious" individual travel-cost method they found that the WTP was in the range of USD 1.04–24.96, with the highest values associated with the Lawachara National Park.

In the Indian part of the Sundarbans, Guha and Ghosh (2009) analysed the WTP of Indians visiting the area. Using the zonal travel-cost method, they estimated an annual total value of about USD 0.38 million in 2005–06, revised up to roughly USD 0.6 million in 2015 (Verma *et al*., 2015).

Symbolic and cultural value of species

Some species – both fauna and flora – are iconic and symbolic. Some are considered flagship species – that is, "popular, charismatic species that serve as symbols and rallying points to stimulate conservation awareness and action" (Heywood, 1995). Thus, flagship species can help raise awareness and funding for conservation efforts (Veríssimo *et al*., 2009). The concept of flagship species is traditionally associated with charismatic large vertebrates such as giant pandas, gorillas, whales and tigers (Leader-Williams and Dublin, 2000; Walpole and Leader-Williams, 2002). The flagship concept has evolved over the years to include "local flagships" – that is, locally significant species, mostly known by local people (Bowen-Jones and Entwistle, 2002) – and "ecotourism flagships", which attract international tourists with an interest in seeing animals in their habitats or in being directly involved in conservation action (Walpole and Leader-Williams, 2002).

Flagship species can help in marketing an area to tourists and therefore create income opportunities; such income can help offset the cost of living with flagship species. Flagship species can also directly attract funds from tourists and non-tourists to support conservation initiatives and projects. Finally, they can help raise awareness about local biodiversity (i.e. beyond the charismatic species).

The Royal Bengal tiger is an example of a flagship species (and also of an umbrella species[68]). According to the latest census, there are 106 tigers[69] in the Sundarbans forests (estimated range: 83–130 units), the only significant tiger habitat left in Bangladesh (Day *et al*., 2015). On one hand, the Sundarbans has one of the most extreme human–tiger conflict situations (in which tigers kill livestock and sometimes people, and are hunted by humans) (Barlow, Ahmad and Smith, 2013; Bangladesh Forest Department, 2010). On the other hand, tigers are used widely in tourism advertising and as symbolic icons (Figure 39). Khanom and Buckley (2015) reported that tourists and visitors are keen to see tigers (and wildlife in general) when visiting the Sundarbans and attribute value to this possibility – even though they rarely see tigers.

India has more experience in managing tiger reserves to attract tourists and favour conservation programmes (Buckley and Pabla, 2012). Verma *et al.* (2015) performed an economic valuation of 6 of the 47 tiger reserves in India,[70] including the Sundarbans Tiger Reserve.

[68] Umbrella species are species the protection of which also indirectly protects the other species that comprise the ecological community of the umbrella species' habitat

[69] The 2004 census estimated 440 tigers Bangladesh Forest Department (2010)

[70] For more information see http://projecttiger.nic.in/content/109_1_ListofTigerReservesCoreBufferAreas.aspx

They found that the TEV of cultural ESs (mostly in terms of tourism and recreational value) generated by the seven reserves was USD 15 million per year. The TEV of cultural ESs in the Sundarbans Tiger Reserve was about USD 0.62 million/year: given that the tiger population in the reserve has been estimated at 76 (with a range of 62–96) (Jhala, Qureshi and Gopal, 2015),[71] each tiger has an estimated value of about USD 8 115 per year (USD 6 400–10 100).

FIGURE 39

The Royal Bengal tiger is a flagship species and icon in Bangladesh

Source: http://visitbangladesh.gov.bd (left) and www.tigercricket.com.bd (right)

Tourism and recreation are marketable cultural ESs, but ecosystems and their components are also culturally important for traditional, historical, symbolic, religious and other reasons. Local flagships can play prominent roles in this framework. For example, Mohammed *et al.* (2016) studied the passive-use value of the hilsa (*Tenualosa ilisha*) fishery in Bangladesh. Hilsa is Bangladesh's most important single-species fishery: landings contribute about 10 percent of domestic annual fish production (FRSS, 2014) and 1 percent of national GDP (Bangladesh Department of Fisheries, 2014; Rahman and Naevdal, 2000): Bangladesh takes 50–60 percent of the total catch. It has been estimated that, in Bangladesh, 0.5 million people are directly dependent on the hilsa fishery, and another 2.5 million are involved in its supply chain (Rahman, Rahman and Bhaumik, 2012). Hilsa also have cultural and religious importance, being used commonly in traditional dishes and ceremonial festivals (Mohammed *et al.*, 2016; Mohammed and Wahab, 2013).

[71] For statistics and updates see www.tigernet.nic.in/Alluser/Default.aspx

Overfishing and the decline of the hilsa catch and stock have been observed in the last 30 years, and there has been insufficient investment to restore the fishery. Given the decrease in catch, the Government of Bangladesh has declared five coastal sites as hilsa sanctuaries in which fishing is banned during the reproductive season for some years. Fisher communities (about 187 000 households) affected by this measure were compensated for lost earnings with 30 kg of rice per household per month, as well as with the provision of alternative income-generating activities (Mohammed and Wahab, 2013). Mohammed *et al.* (2016) used contingent valuation to estimate the WTP of residents in Barisal Division (in southern Bangladesh) for passive-use (sociocultural, religious and sentimental) benefits of a hypothetically restored hilsa fishery. Using stratified random sampling, 1 006 households were surveyed in five districts in the division. Respondents comprised both fishers and non-fishers and were generally representative in terms of livelihoods, incomes, distance from rivers and other relevant variables. Respondents were told about the hypothetical National Hilsa Fish Restoration Programme and asked whether (and how much) they would be willing to pay for this. Payments would be in the form of additional fees on local taxes (buildings and landholding tax), which would fund the (also hypothetical) National Hilsa Conservation Foundation. Box 27 shows the hypothetical market scenario presented to respondents and the payment card used for the contingent valuation exercise. The total value of hilsa fishery restoration in Barisal Division was estimated at USD 8.3 million–17.7 million per year. Extrapolated to the national scale, the total value would be USD 167.5 million–355.7 million per year.

BOX 27

Hypothetical market scenario and payment card used for the contingent-valuation exercise on hilsa fishery restoration

Hilsa is the most preferred fish of the people of Bangladesh and West Bengal in India and is of religious and cultural importance, forming part of Bengali festivals. Hilsa has been recognized as the "national fish" of Bangladesh. In some Hindu Bengali families, large hilsa fish are bought for engagements and pre-wedding ceremonies. One such important occasion is the *Jamai Sashti*, when the son-in-law visits his prospective parents-in-law. A *Jamai Sashti* meal is never complete without at least one dish of hilsa, and it is often expected that the bridegroom will bring a pair of hilsa for the occasion.

Pohela Boishakh, the first day of the Bengali New Year, is ceremonially observed in both Bangladesh and the Indian state of West Bengal as a national day. Bengali communities celebrate *Pohela Boishakh* with a special menu of *Panta-Ilish* (fermented rice and fried hilsa).

Recent and significant declines in catches have pushed up prices, meaning most low-income groups can no longer afford to buy hilsa. Decline in hilsa fish stock also poses a major threat to the socio-cultural benefits of the fishery. Significant investment is required to reverse

Box 27 continues on next page

Box 27 continued

the trend to the pre-1970s situation when hilsa was available in all major rivers, the average weight of caught fish was 800 g (compared with around 300 g now), and most people could afford to buy the fish. Fisheries managers and experts were asked what would be needed for a national hilsa fish restoration programme. They suggested a 10-year programme to:

- dredge river beds;
- control pollution;
- compensate fishers for adhering to a fishing ban during the spawning season; and
- boost capabilities to enforce the closed season and ban on harmful fishing gear (such as the jal).

Such a national programme would require a large amount of money. Each household would need to pay a monthly contribution towards the programme over the ten years. The payment would be an additional fee on Union Parishad taxes (on buildings and land holding tax) and would be directed to a National Hilsa Conservation Foundation – which would administer the fund and work closely with the government and fisher communities to implement restoration activities.

Willingness-to-pay elicitation question

What is the highest amount of money in Bangladeshi Taka, if anything, that your household would pay **each month for the next ten years** to make a **National Hilsa Fish Restoration Programme** possible?

(Circle the highest amount at which your household would still vote for the programme).

0	20	40	60	80	100	130
150	180	210	240	300	350	400
500	600	700	800	900	1 000	1 500
2 000	3 000	4 000	>5 000			

If more than BDT 5000, then how much?

Source: Mohammed *et al*. (2016).


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Module 8 Using valuation results in policymaking and decision making

KEY MESSAGES

- The assessment and valuation of ESs can be used to compare alternatives; identify opportunities; design policy instruments; scope projects; enhance environmental awareness; manage environmental conflicts; and assess the impacts of policy changes.
- A three-tiered approach can be used in the valuation of ESs and their inclusion in decision making: 1) *recognizing ESs* (Who has a stake in ESs? Who will be affected by policy changes and their effects on ESs? Who can provide information?); 2) *demonstrating the value of ESs* by choosing and implementing appropriate economic valuation methods (including considering scenarios in terms of the delivery of ESs); and 3) *capturing the value of ESs* – that is, seeking solutions to the undervaluation of ESs by selecting from a range of economically informed policy instruments.
- The main limitations of using ES valuation in policy decisions are cultural, technical/methodological, and political.
- Policymakers and the public at large sometimes have difficulty in understanding ESs and their valuation. The effective communication of valuation results to decision makers and other relevant audiences, therefore, is crucial. It requires the use of appropriate terminology and communication tools and channels.

ES valuation has been the subject of a broad and fast-growing literature since the early 1990s (e.g. Adamowicz, 2004; Costanza, Farber and Troy, 2010). Increasingly, such valuations need to be considered as a resource for decision making and in policy and project design (Laurans *et al*., 2013). Advocates have high expectations that (economic) assessments and valuations of ESs can influence policies aimed at averting the degradation of ESs and biodiversity loss (Heal *et al*., 2005). This module looks at how valuation studies are being used to inform policymaking.

8.1 PURPOSES OF ECOSYSTEM SERVICE VALUATION

Berghöfer *et al*. (2015) identified the following seven basic purposes for the assessment and valuation of ESs (Table 32):

1. **Comparing alternative policies, programmes and projects.** How do alternatives differ in terms of ES gains and losses?
2. **Identifying livelihood, development and investment opportunities.** What new or improved economic opportunities can be developed based on the conservation and sustainable use of ESs?

3. **Designing environmental policy instruments, including incentives, regulations and monitoring.** What information on ESs will enable the design of effective, equitable and sustainable environmental policy instruments?
4. **Undertaking scoping and situation analysis.** What is the state of ESs in a given context, and what values and stakeholders are associated with them?
5. **Enhancing environmental awareness or advocating for a policy option.** How can information on the provision and impacts of ESs be used to "make the case" for a given policy option?
6. **Tackling environmental conflicts.** How can a focus on ESs provide credible information on environmental change to help resolve conflicts?
7. **Appraising and assessing impacts of policy changes.** How can ES valuation inform choices on, for example, competing uses (e.g. land uses) and funding priorities?

TABLE 32. **Purposes of ecosystem service assessment relevant to Bangladesh and nearby countries**

Purpose	**Possible assessment question**	**Examples relevant to Bangladesh** (and nearby countries)
Comparing alternative policies, programmes and projects	How do alternatives differ in terms of the gains and losses of ecosystem services (ESs) they are likely to produce or that are likely to arise from their implementation?	Assessing options for coastal protection for a range of grey and green infrastructures, including mixes of these
Identifying livelihood, development and investment opportunities	What new or improved economic opportunities can be developed based on the conservation and sustainable use of ESs?	Assessing the recreational value of coastal areas, including the Sundarbans, to identify possible investment strategies to promote responsible tourism as a driver of local development
Designing environmental policy instruments, including incentives, regulations and monitoring	What information on ESs will enable the design of effective, equitable and sustainable environmental policy instruments?	Assessing the value of carbon sequestration by afforestation projects in the Chittagong Hills to access carbon markets and generate revenues that could support reforestation and related co-benefits (e.g. woodfuel production and a reduction in soil erosion)
Undertaking scoping and situation analyses	What is the state of ESs in a given context, and what values and stakeholders are associated with them?	Stakeholder consultation and ES assessment to identify the perceived importance of ESs among groups and to set priorities for forest management (e.g. harvesting intensity and the frequency and size of set-asides)
Enhancing environmental awareness or advocating for a policy option	How can information on the provision and impacts of ESs be used to "make the case" for a given policy option?	Meetings with stakeholders and experts to assess the impacts of mangrove forest restoration compared with those associated with aquaculture development in coastal areas and to inform decisions by local policymakers
Tackling environmental conflicts	How can a focus on ESs provide credible information on environmental change to help resolve conflicts?	Meetings with stakeholders and experts to manage human–tiger conflicts in the Sundarbans
Appraising and assessing the impacts of policy changes, thus informing choices among competing uses	What are the impacts on competing resource uses of changes in existing policies?	Assessing the impacts of forest policy changes in the conversion of forests to agricultural land uses (e.g. oil-palm plantations), or of the conversion of coastal wetlands to aquaculture (e.g. shrimp farming)

Source: Modified from Berghöfer *et al.* (2015).

8.2 INCLUDING ES VALUATION IN DECISION MAKING: A STEP-WISE APPROACH

Including ES valuation in decision making is a three-step process: 1) recognizing ESs; 2) demonstrating ESs; and 3) capturing ESs (Daily *et al*., 2009; TEEB, 2010c).

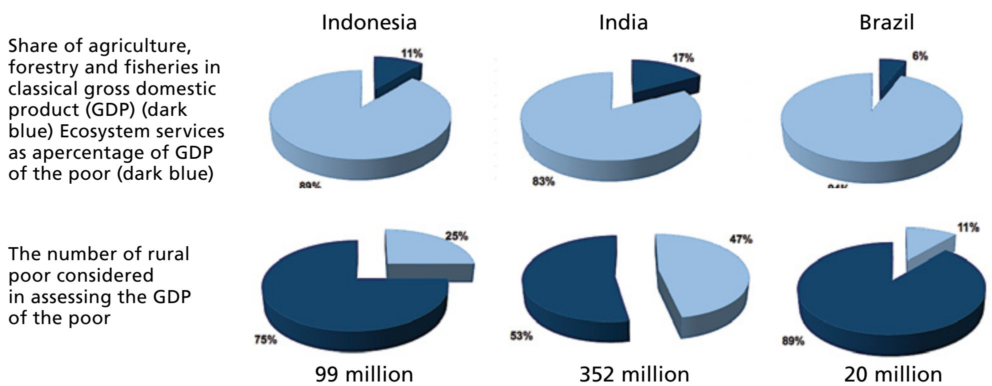
Recognizing ecosystem services

Recognizing ESs involves first assessing the links between policy changes and changes in ecosystem functions and between those and ESs. Classical ecology and conservation biology can help in analysing the impacts of land-use change on biodiversity or ecosystem resilience. Ecological production functions can be used to assess the condition and status of ecosystems (e.g. under different management regimes) and thereby the supply of ESs. It is also important to identify the stakeholders influencing or benefiting from ESs and how they might be affected by policy changes. In broader terms, this means also considering who has an interest in or will be affected by policy changes, who might be able to inform the valuation process, and who comprise the target audience for the valuation results (Waite, Burke and Gray, 2014).

Studies have shown that, in some countries, ESs and other non-marketed goods account for 47–89 percent of the "GDP of the poor".[72] On the other hand, agriculture, forestry and fisheries account for just 6–17 percent of national GDP (TEEB, 2010c) (Figure 40). This means that the value of forests and other ecosystems to poor rural households differs significantly from the value captured by classical economic tools and indicators such as GDP. Assessing the GDP of the poor, therefore, is important for informing policymakers about the potential of conservation efforts to reduce poverty.

FIGURE 40

GDP of the poor: estimates of dependence on ecosystem services in selected countries



Source: Modified from TEEB (2010c).

[72] GDP of the poor is the effective GDP or total sources of livelihood of rural and forest-dwelling poor households, taking into account the sectors in national accounts that are directly dependent on the availability of natural capital – agriculture and animal husbandry, forestry and fisheries.

Demonstrating ecosystem services

Demonstrating ESs requires selecting and implementing the appropriate economic valuation methods. Such selection depends on several factors, including the ESs being assessed; the type of value (e.g. use or passive-use); the aim of the valuation; the availability of, and access to, data; data quality; and budgetary, technical and time constraints. Valuation is best used for assessing the consequences of changes in the provision of ESs arising from different management options, rather than attempting to estimate the total value of ecosystems (TEEB, 2010c). A good approach is to identify and analyse scenarios defined with the support of experts and based on the inputs of stakeholders. Scenarios should be consistent and plausible visions of the future, taking into account existing information and projections. This enables the:

- quantification of the **likely changes in ESs** under each scenario;
- tracking of **changes in social and environmental metrics** (e.g. forest area, growing stock, carbon stock and number of species); and
- translation of changes into **monetary values** using appropriate economic valuation methods (Waite, Burke and Gray, 2014).

Valuing certain ESs using existing methods might be difficult or even impossible; nonetheless, it is important to identify all significant changes in ESs that may occur in the various scenarios, including those that cannot be monetized. Scenario building and analysis can be done using various approaches, such as the following:

- **Modelling**. This might involve the use of dedicated ES-modelling tools such as InVEST[73] – Integrated Valuation of Ecosystem Services and Tradeoffs – and ARIES[74] – Artificial Intelligence for Ecosystem Services. Christin, Bagstad and Verdone (2016) reviewed ES modelling tools using a study by Bagstad *et al.* (2013). Annex 5 contains a list of such tools, and additional information is available in Pandeya *et al.* (2016).
- **Experts.** Professionals with expertise in the economic effects of ESs provide inputs and outline the expected impacts of policy changes (e.g. via focus groups or using the Delphi method) (e.g. Mukherjee *et al.*, 2014).
- **Analysis of similar cases.** The impacts and effects observed in similar cases are identified and transferred or adapted to the current situation.
- **Mixed approaches**. A combination of two or more of the above is used (e.g. modelling and experts, or experts and the analysis of similar cases).

Assessments of changes in ESs and their value under different scenarios should aim to inform decision makers about distributional effects – that is, the distribution of impacts among stakeholders arising from changes in ESs (Who is affected?), as well as the spatial/geographical (Where will the impacts occur?) and temporal (When will the impacts occur?) distributions. Box 28 provides an example.

[73] www.naturalcapitalproject.org/invest/
[74] www.ariesonline.org

BOX 28

Developing, assessing and mapping future scenarios for the valuation of ecosystem services

Goldstein *et al.* (2012) developed seven scenarios for assessing the value of ecosystem services in a 10 600-ha area on the Island of O'ahu, Hawaii, United States of America. Scenarios were developed according to three main decision options using the InVEST software tool to support decision making on an investment of USD 7 million. Investment options included improving the region's aging irrigation system to sustain and enhance agricultural production, and others (Table 33). Each scenario was associated with different changes in land use and land cover (Figure 41).

TABLE 33. **Decision alternatives and future scenarios for a case study on O'ahu, Hawaii**

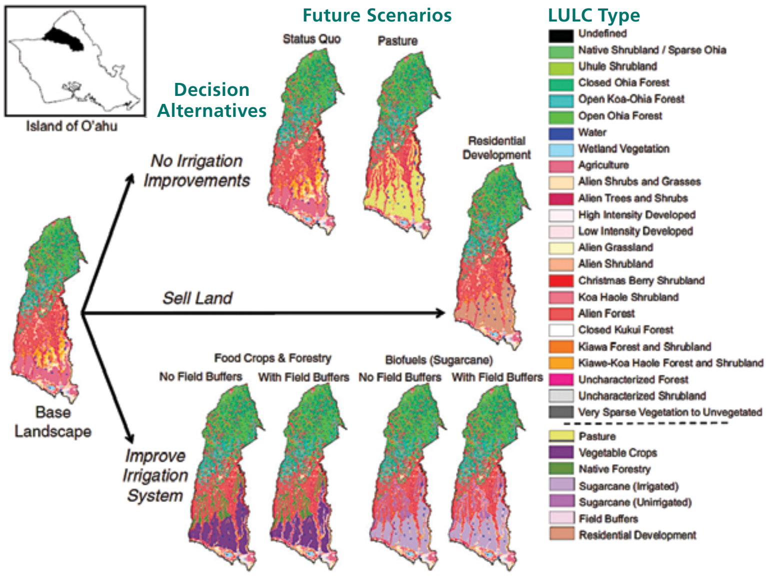
Decision alternative	Scenario
A. No improvement in irrigation system	1. Status quo (maintaining current land uses into the future)
	2. Pasture (converting all fields to pasture for cattle grazing)
B. Improvement in irrigation system	3. Food crops and forestry (using lower irrigated fields for diversified food crops and upper fields for forestry plantings)
	4. Biofuels (returning agricultural lands to sugarcane to produce energy feedstock)
	5. Food crops and forestry with field buffers (vegetative buffers added to fields adjacent to streams to reduce nutrient and sediment run-off)
	6. Biofuels with field buffers (vegetative buffers added to fields adjacent to streams to reduce nutrient and sediment run-off)
C. Sell land	7. Residential development (agricultural lands sold for a housing development)

Source: Modified from Goldstein *et al.* (2012).

Box 28 continues on next page

Box 28 continued

FIGURE 41
Mapping decision alternatives and future scenarios for a case study on O'ahu, Hawaii



Source: Goldstein *et al.* (2012).

Scenarios were assessed according to three main metrics:

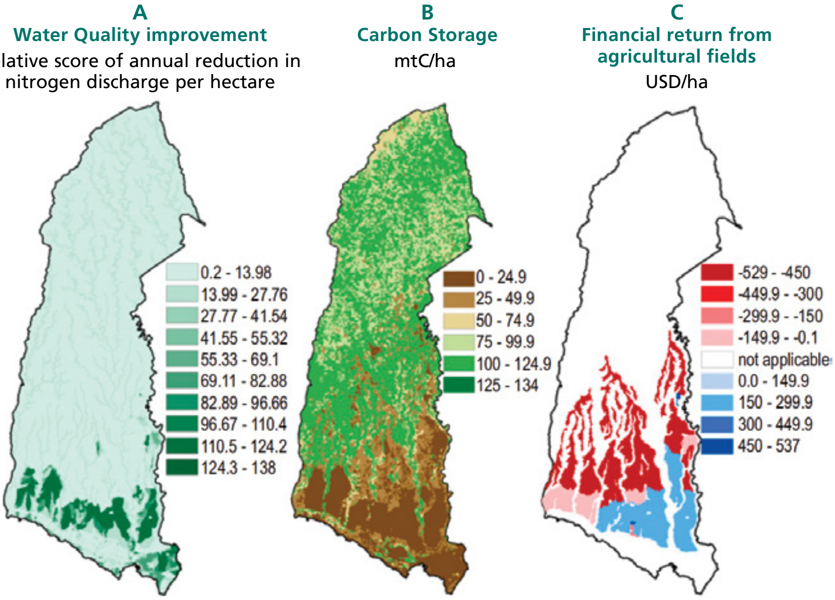
1. **carbon storage,** calculated as the carbon fraction in above- and belowground biomass;
2. **water-quality improvement**, estimated as the relative export of total dissolved nitrogen. Nitrogen was used as a proxy for pollution given the nearness of the agricultural land to the ocean – nitrogen is generally considered a limiting nutrient in marine systems; and
3. **economic return,** estimated as net present value (NPV) using a discount rate of 6 percent over a 50-year time horizon. Sensitivity analyses were performed at discounts of 3 percent and 12 percent.

The three metrics were first assessed for the status quo scenario. The main carbon stocks are in the upper-elevation forests, and agricultural fields are the main source of nitrogen (with developed areas downstream of the fields also of concern). Less than one-third of the agricultural area was originally rented for income generation. Given taxes and management costs and relatively low revenues (only USD 0.1 million per year from agriculture), the status quo scenario incurred an annual financial loss of USD 0.53 (Figure 42).

Box 28 continues on next page

Box 28 continued

FIGURE 42
Metrics for the status quo scenario



Source: Goldstein *et al.* (2012).

Figure 43 shows relative changes in the three metrics associated with each scenario. For carbon storage and water quality, no scenarios represented lose–lose or win–win outcomes relative to the status quo. Water quality increases in the pasture, biofuels, and biofuels-with-field-buffer scenarios, but carbon storage declines in all these. On the other hand, carbon storage increases in the food-crops-and-forestry, food-crops-and-forestry-with-field-buffers, and residential-development scenarios, but water quality declines in all these. Field buffers can increase carbon storage and water quality compared with the same scenarios without buffers, but they involve trade-offs because land is taken out of agricultural production, thus reducing the financial return (USD 1.9 million for both scenarios with buffers), although overall NPVs remain positive.

Local stakeholders were not in favour of selling land, and they identified a potential conflict between pursuing a strict financial profit-maximizing strategy and nonfinancial values. Thus, although the residential-development scenario had the best financial performance, it was not taken into account. The study also analysed a hypothetical full native-vegetation-restoration scenario, finding that it would deliver the biggest increase in carbon storage (+30.4 percent compared with the status quo) and the greatest improvement in water quality (+46 percent over the status quo).

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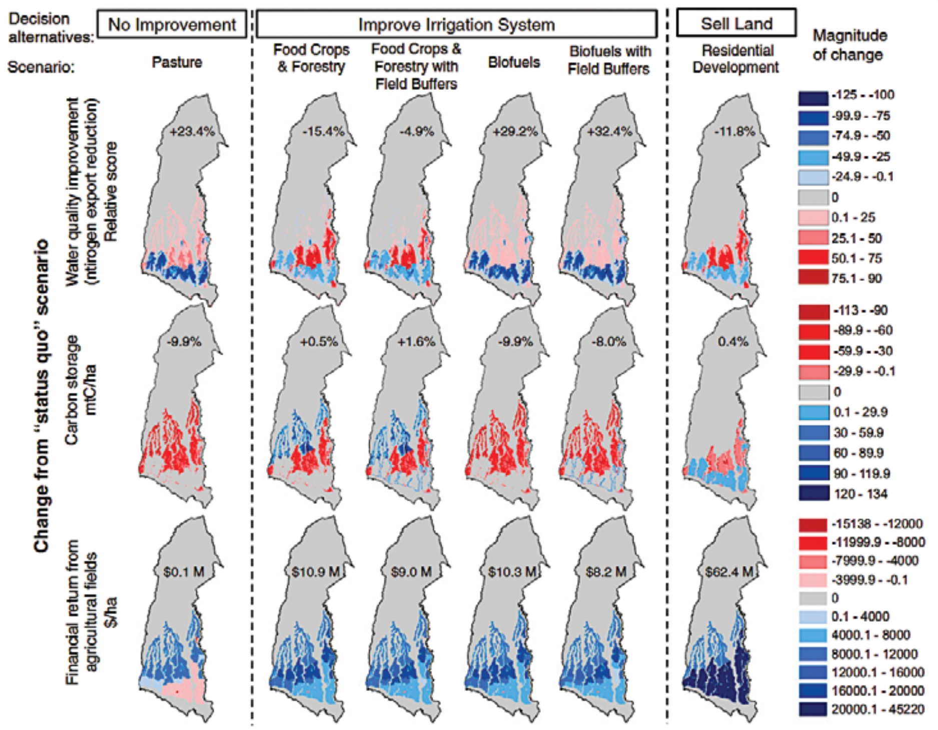
Box 28 continued

FIGURE 43
Differences from status quo in three metrics, by scenario



Source: Goldstein *et al.* (2012).

Demonstrating the economic value of ESs and the impacts of changes in their delivery is important, even when it is not possible to capture value. The demonstration of economic value can support decision makers in addressing trade-offs among management choices and land uses by helping identify the most efficient use of natural resources and means of delivering ESs (TEEB, 2010c). Examples of how the economic valuation of ESs can inform and support decision making are provided by (among others) The Nature Conservancy (2007) for watershed management in Indonesia and by Emerton and Bos (2004) and the United Nations Development Programme and the United Nations Environment Programme (2008) for wetland conservation in Uganda (see Box 16 in Module 4). In the first case, in Indonesia, the value of regulating water-related ESs from the Segah and Kelay watersheds was estimated at more than USD 5.5 million per year: as a consequence, the Segah Watershed Management Committee was established to protect the watershed. In the second case, in Uganda, the value of the wastewater cleaning services provided by

Nakivubo Swamp to the Greater Kampala Metropolitan Area was estimated using the substitute approach (i.e. the cost of building a sewage-treatment plant and additional technologies) at around USD 2 million per year; consequently, plans to drain and reclaim the wetland were abandoned and the area was designated as part of the city's greenbelt zone. Box 29 provides another example, from Thailand.

BOX 29

Mangrove conservation and shrimp farming: a case study in Thailand

Sathirathai and Barbier (2001) compared the economic returns of shrimp farms with those of sustainably managed mangroves in Tha Po village in southern Thailand. Mangrove deforestation affected the area significantly in the 1990s, with more than 50 percent of the mangroves cleared for commercial shrimp farming, supported by outside investors. The study analysed the economic value of the remaining 400 ha of mangrove forests for local households. In particular, three ESs were valued, as follows:

1. **Timber, woodfuel and other forest products** were valued based on the net household income they generated. Market prices were used for those products sold on markets, and the closest substitute goods were used for valuing self-consumed products. The estimated value of these products was about USD 88/ha.
2. The value of the **offshore mangrove-dependant fishery** was estimated using the production function approach in the range of USD 21–69/ha.
3. **Coastal protection and stabilization** was valued through the cost of substitute goods (a 1-m-wide breakwater). To minimize the risk of overestimation, the value was not calculated for the entire coastline but only for the area subject to severe erosion and requiring protection (i.e. 30 percent of the coast). The estimated value was USD 3 679/ha per year.

Therefore, the total value of mangrove forests in the provision of the three ESs was USD 3 787.62–3 835.70/ha. Assuming a 10 percent discount rate and a 20-year time line, the total NPV is USD 35 470.72–35 920.28/ha.

A cost–benefit analysis (CBA) of commercial shrimp farming (including the value of subsidies) found that it produced financial returns of USD 7 707–8 336/ha. An economic CBA was also performed to take into account the cost of subsidies as well as the following environmental externalities: water pollution due to agrochemical runoff and increased salinity (valued through the cost of chemical treatments of polluted water and reduced farm income from rice production as a result of saline water released by ponds); and the degradation of coastal areas when ponds are abandoned after five years of productive life (valued through the cost of restoring mangrove forests). The economic CBA estimated a negative NPV of USD 5 442.97/ha. When the cost of mangrove restoration was excluded, the NPV was USD 209.36/ha. Figure 44 summarizes the results of the CBAs.

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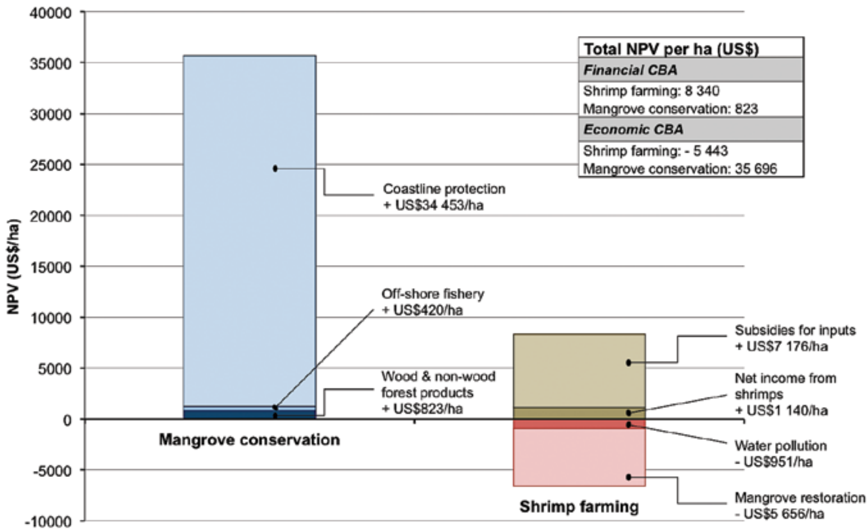
Box 29 continued

FIGURE 44
Results of financial and economic cost–benefit analyses for mangrove conservation and shrimp farming in Thailand



Source: Developed based on data from Sathirathai and Barbier (2001).

A financial CBA, which does not take into account non-monetized environmental costs and benefits, indicates that shrimp farming is more profitable than mangrove conservation. An economic CBA, however, which excludes subsidies and includes the benefits provided by ESs, shows that mangrove conservation is vastly more valuable than shrimp farming (which, in fact, has a net negative economic impact). If commercial shrimp farmers were required to restore mangroves when they abandoned their ponds, shrimp farming in the area would be neither financially or economically viable.

Capturing the value of ecosystem services

The economic trade-offs involved in delivering ESs is a key challenge for decision makers. Even when it has been estimated, the value of many ESs remains external to markets and a gap exists, therefore, between the recognition of the economic value of ESs to society and the financial benefits available to landowners, managers and other stakeholders (Daily *et al*., 2009). Capturing the value of ESs is about seeking ways to fill this gap and therefore overcoming the undervaluation of ESs. A wide range of economically informed policy instruments is available, in four main categories (IPBES, 2016): 1) legal and regulatory instruments; 2) rights-based instruments and customary norms; 3) economic and financial instruments (or market-based instruments); and 4) social and cultural instruments. Such categories have largely been considered independently in the past, with a strong focus on market-based instruments (Pirard and Lapeyre, 2014), particularly PES (see Box 30 and Box 31), but there is growing attention on policy-mix approaches (Ring and Schröter-Schlaack, 2011). In some cases, mechanisms set up to support forest conservation measures have failed due to poor and inappropriate governance (see Box 32 and Box 33).

8.3 BARRIERS TO THE USE OF ECONOMIC VALUATION

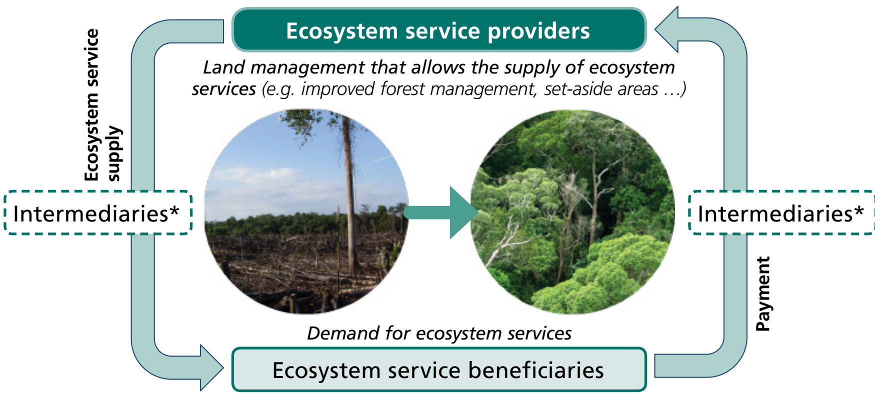
BOX 30

Payments for ecosystem services

Based on the definition given by Wunder (2005), a payment for an ecosystem service (PES) is a voluntary transaction in which a well-defined ecosystem service (ES) (or a land use likely to secure that service) is "bought" by one or more buyer from one or more provider, if and only if the ES provider secures the provision of the ES (i.e. conditionality) (Figure 45).

FIGURE 45

Payments for ecosystem services: a general scheme



Note: Intermediaries are not part of the PES definition developed by Wunder (2005), but they are often present in PES implementation as facilitators between suppliers and beneficiaries, generating transaction costs.

Therefore, a PES scheme is a voluntary, negotiated market-based instrument different from command-and-control tools (e.g. regulations and taxes). It requires that ES providers have real land-use choices – that is, they can decide how to manage their land and which land use to deploy. The object of a PES scheme must be a well-defined ES (e.g. a certain amount of carbon sequestered by a forest) or a land use that can generate a certain ES (e.g. a forest area with a well-known growing stock). Moreover, there should be at least one ES

Box 30 continues on next page

Box 30 continued

buyer and at least one provider, even though the transfer can occur through one or more intermediaries. Finally, the payments made by buyers are contingent on the provision of ESs by providers; thus, buyers directly or indirectly monitor that the ESs are being provided and that the management practices that generate them are being implemented. When one or more of these features is not (fully) present (e.g. the agreement builds on a normative requirement in which ES beneficiaries are obliged to make payments), the situation may be referred to as PES-like or quasi-PES.

UNECE and FAO (forthcoming) provide detailed information on how to set up and manage PES schemes, as well as examples of PES initiatives involving forest management and water-related ESs. A rich literature is also available (see, for example, FAO, 2011). Examples of market-based initiatives and marketplaces for forest services, including PES initiatives, are available in Forest Trend's Ecosystem Marketplace[75] and OpenForests Marketplace.[76]

BOX 31

Costa Rica's national programme of payments for ecosystem service

Forest cover in Costa Rica decreased dramatically from 70 percent in 1950 to about 20 percent in the mid-1980s. The conversion of forests to agriculture and cattle ranching was driven by a combination of national policies encouraging the colonization of new lands, an ineffective domestic normative framework, and high international prices for beef and agricultural crops such as coffee and bananas. A shift towards re-greening the country began in the early 1990s with the introduction of the first reforestation incentives: although these were ineffective in stopping deforestation and promoting reforestation, they opened the way for the creation of the national "payments for ecosystem services" (PES) programme. The programme was introduced in the Forestry Law passed in 1996, which built on two main tools: a ban on forest conversion, and the development of payments for reforestation and the protection and sustainable management of existing forests on private lands to complement public protected areas. The National Forestry Fund (FONAFIFO) was created to manage the PES programme: operating as an intermediary, FONAFIFO contractually agrees on land use and management with landowners and monitors compliance with the agreed terms by means of dedicated staff. Landowners complying with the agreed management practices receive payments and, in turn, transfer the rights for the ESs generated by their forests to FONAFIFO. The demand for ESs is driven at the national level by tax revenues from water and fossil fuels, as well as (in lesser amounts) by forestry and conservation trusts and voluntary agreements with private and semi-public companies (e.g. hydropower plants). International markets also generate demand and revenue through the sale, for example, of carbon credits (Figure 46). Loans and international agreements supported the programme in its early stages.

Box 31 continues on next page

75 www.ecosystemmarketplace.com
76 https://marketplace.openforests.com

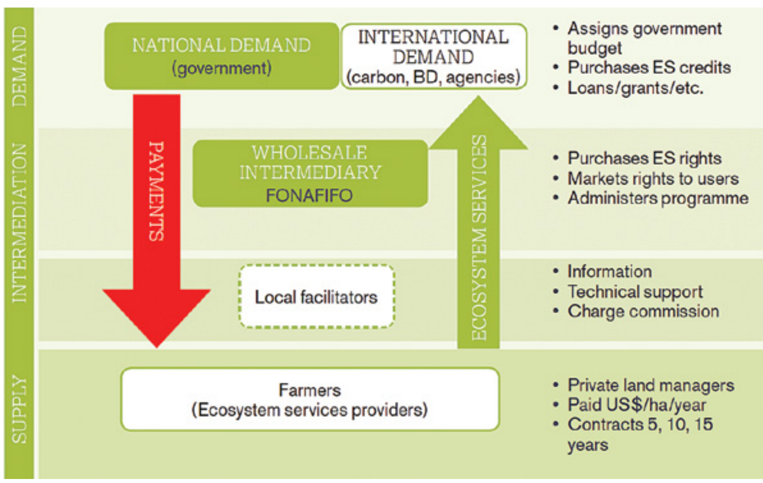
Box 31 continued

The PES programme delivers four ESs: 1) carbon sequestration; 2) water services (the protection of water catchments); 3) biodiversity conservation; and 4) scenic beauty. The provision of these ESs involves five land-use types: 1) forest protection; 2) commercial reforestation; 3) agroforestry; 4) sustainable forest management; and 5) the restoration of degraded areas. Each land-use type (or their subcategories) is associated with a specific level of payment, which is ensured through long-term contracts involving annual payments to landowners committed to the programme. Payment amounts are mostly made per ha, with limited variations for forest areas near water sources and reforestation projects making use of native species.

The programme is accessible to any private landowner with a property title or possession rights and with a minimum land area of 1 ha. Between 1997 and 2012, FONAFIFO distributed approximately USD 340 million to legal entities (49 percent), individuals (31 percent), indigenous groups (13 percent) and cooperatives (7 percent), resulting in the protection of more than 860 000 ha of forest areas; the reforestation of 60 000 ha; the sustainable management of 30 000 ha of forests; and the natural regeneration of 10 000 ha. Combined, a total of 1 million ha is subject to the programme, along with 4.4 million trees planted in agroforestry systems. As of 2010, about 52 percent of the national land area was under tree cover. Since its launch, the programme has promoted conservation activities at an average of 60 000 ha per year. The number of contracts has remained more or less stable since 2007, at about 1 300 contracts per year, despite a decrease in the real value of payments over time. Among the positive impacts of the national PES programme is the increased participation of indigenous communities and women-led properties, the creation of job opportunities, support for the regularization of property ownership among smallholders, and increased compliance with social-security obligations for farm employees.

FIGURE 46

General structure of, and the main actors in, Costa Rica's national payments for ecosystem services programme



Source: Porras *et al.* (2013).

BOX 32

Compensation for diverted forests in India: the Godavarman case

The Indian Forest (Conservation) Act 1980 (FCA) defines non-forest use as the breaking up or clearing of forest land for any purpose other than reforestation. The FCA, and rules framed therein, sets the procedure for diverting forests to non-forest uses, requiring that each change of forest land to a non-forest land use is compensated through afforestation to be carried out in compliance with guidelines defined by India's Ministry of Environment and Forests. According to these guidelines, compensatory afforestation is required on an area of non-forest land equivalent to the area being diverted, or double the area if the land to be forested is degraded forest land. Special provisions apply to certain categories of projects, such as those undertaken by the central government and for public utility. Between 1980 and 2009, about 11.4 million ha of forest lands were converted to non-forest land uses within the framework of the FCA procedures.

In 1995, the Godavarman Thirumalpad versus Union of India case (W.P. (Civil) No. 202 of 1995[77]), popularly known as "the Godavarman case", was brought in the Supreme Court. The Godavarman case has resulted in important changes in policy for the diversion and administration of non-forest land based on several reports and studies, as well as orders passed by the Supreme Court on the implementation of compensatory afforestation.

Before the Godavarman case, the money for compensatory afforestation was deposited with the state government by the agency responsible for the forest diversion, which was thus left with the responsibility of implementing the afforestation activities. A 2002 report by the Central Empowerment Committee found that only 60 percent of the total funds for compensatory afforestation (the Compensatory Afforestation Fund – CAF) deposited by user agencies had been used and only 61 percent of the total target area had been achieved. Based on the recommendations of this report and orders passed by the Supreme Court, new mechanisms for the disbursement and management of afforestation funds were set up. The Compensatory Afforestation Planning and Management Authority (CAMPA) was created and net present value (NPV) was adopted as a parameter for the aims of forest valuation. NPV was defined as the amount to be paid for the diversion of forests in addition to the CAF (and any other applicable payment associated with diversion practices) in order to compensate for the loss of natural forests and the tangible and intangible benefits associated with them. Various parties seeking exemptions from the requirement to pay the NPV (e.g. agriculture and irrigation projects, hydropower plants and mineral industries) raised objections, and the Ministry of Environment and Forests sought standardized procedures for calculating NPV. The Supreme Court held that – apart from non-revenue-earning public-utility projects such as schools and village roads – no other exemptions from NPV were allowed.[78]

By 2009, CAMPA had collected a large amount of funds, and guidelines for their use were needed. It was decided that 10 percent of funds pertained to each state. Five states contributed more than 50 percent of the funds, however, and these states were dissatisfied with the

Box 32 continues on next page

[77] Official documents and additional information are available at www.forestcaseindia.org

[78] The Kanchan Chopra Committee made additional and partly different recommendations in 2005.

Box 32 continued

idea of receiving just 10 percent of the resources. Guidelines for the use of the funds held that funds were to be distributed to the state arms of CAMPA, which were to disburse the funds to the forest officials in predetermined instalments to finance activities such as natural assisted regeneration, forest management and wildlife protection. An assessment of 2010–2011 disbursements, however, found that some states had used up to 67 percent of their NPV budgets for infrastructure (e.g. offices) and equipment (e.g. vehicles and laptops). Moreover, many states had allocated large sums to the creation of forest plantations, including monoculture production forests, to compensate for the diversion of natural forests.

Despite recent developments and the introduction of monitoring mechanisms by some states, the improper use of funds for compensatory afforestation remains problematic in India – as highlighted recently in the Indian media[79] based on the most recent available official data. The mechanism seems not to have been fully effective in achieving its core purpose – ameliorating the negative impacts associated with forest conversion to other land uses.

Source: Kohli *et al.* (2011).

BOX 33

Indonesia's Reforestation Fund

Indonesia's Reforestation Fund (*Dana Reboisasi*) was established in 1989 as a national forest fund financed by a volume-based levy paid by timber concessionaires. Its aim was to sustain national forests in the long term by supporting public investments in reforestation and the rehabilitation of degraded forest lands. The levy ranged from as high as USD 20 (per m^3 of ebony) to as low as USD 2 (per tonne of pulpwood), depending on species, product and subnational region.

In the first decade (1989–1998), the Government of Indonesia collected approximately USD 2.6 billion through the Reforestation Fund and earned an additional USD 1 billion in the form of interest on loans. The amount generated annually ranged between USD 395 million and USD 540 million, including interest; it was the main source of government revenue from Indonesian commercial forestry. Money raised through the payment of levies was deposited into an off-budget fund under the direct responsibility and management of the Ministry of Forestry, with limited oversight on how funds were used. More than USD 1 billion was allocated to commercial forest plantations through cash grants and (less frequently) discounted loans to state-owned forestry enterprises and joint ventures between such state-owned forestry enterprises and private companies. Among other impacts, this allocation favoured capital accumulation among the most powerful companies and actors and the displacement of forest-dependent communities and other players. Many companies that benefited from Reforestation Fund grants were also able to clear the remaining natural forests on their plantation concessions, paying very low royalty fees on the harvested timber.

Box 33 continues on next page

79 See, for example, www.indiaspend.com/cover-story/only-6-compensation-to-repair-destroyed-forests-mis-used-60062

Box 33 continued

In many cases, companies did not create plantations after clearing natural forests. A third-party financial audit conducted by Ernst & Young in 1999 (as a condition for a rescue package issued by the International Monetary Fund – IMF) reported systematic fraud (e.g. marked-up costs and overreported planted areas), financial mismanagement and the diversion of funds to non-forestry uses. Rather than supporting reforestation and forest rehabilitation, subsidies to forest plantations made through the Reforestation Fund had become a perverse incentive for deforestation, with an estimated 1.3 million ha of natural forests converted to industrial plantations and a corresponding loss in foregone rent to the government. Additionally, many of the loans from the Reforestation Fund were not repaid according to the agreed schedule.

In 1998–1999, during the *Reformasi* (i.e. reform) period and following stipulations by the IMF, the Reforestation Fund was transferred to the Ministry of Finance and integrated within the State Treasury, thus becoming part of the government budget. Checking and monitoring activities were introduced to make the system more accountable. Despite these efforts, as well as Indonesian Government initiatives to tackle corruption and increase administrative transparency, recent audits by Indonesia's Supreme Audit Board identified irregularities in the funds administered by the Ministry of Forestry. The management of the Reforestation Fund remains inefficient: for example, the newly created Forest Development Funding Agency Public Service Unit, which manages USD 2.2 billion from the Reforestation Fund, was unsuccessful in disbursing USD 500 million planned for plantation development in 2008–2009. Since 2001, governments at the district and provincial levels have received another USD 500 million through the Reforestation Fund but lack the competencies and human resources to manage these funds effectively.

Lessons learned in developing and implementing the Reforestation Fund should be taken into account in REDD+ schemes, which have enormous potential as payment mechanisms for reducing deforestation. According to preliminary estimates, a 5 percent reduction in the deforestation rate in Indonesia could generate payments of up to USD 765 million annually, and a 30 percent reduction would generate more than USD 4.5 billion. Turning this potential into effective payment flows requires appropriate mechanisms and institutions to ensure good financial governance.

Source: Barr *et al.* (2010).

For each ES provided in the area you analysed in the reflection points in Module 1, identify:

- the stakeholder groups with an interest in the ES; and
- the extent of their dependency (e.g. low, medium and high) on the ES (e.g. Do cost-effective substitutes exist for the ES? Are they accessible?)

Discuss your findings with colleagues.

Table 34 provides an example of such as assessment.

TABLE 34. **Dependency of stakeholder groups on ecosystem services in a natural forest in the ABC Forest District**

Ecosystem service according to the Common International Classification of Ecosystem Services				Stakeholder groups	Dependency (Low, medium or high)
Section	Division	Class	Ecosystem service		
Provisioning	Food	Wild animals and their outputs Wild plants, algae and their outputs	Game and wild forest products (e.g. herbs and fruit)	Communities in the region Local traders Biodiversity conservation groups	High Medium to high Medium to high
Provisioning	Materials	Fibres and other materials from plants, algae and animals for direct use or processing	Timber	Communities in the region Timber companies Employees	Low Medium to high High
Provisioning	Energy	Plant-based resources	Woodfuel	Communities in the region	High

Notes: Selected ecosystem = natural forest. This is a hypothetical situation.

Reflection point continues on next page

Reflection point continued

Define a possible policy change or decision in the area (e.g. new land management, change in land use or new investment) and determine its possible impacts by addressing the following questions:

- How are ESs likely to be affected – in terms of their state – by the decision?
- What are the expected spatial and temporal scales of the decision?
- Which groups are likely to be most affected by the decision?
- Is the supply of any ES likely to fall below demand?
- Could the decision push ESs below biological thresholds, leading to a scarcity of ESs or to irreversible changes?

Discuss your findings with colleagues.

Identify at least two scenarios – the status quo (i.e. how the situation would evolve if there was no intervention and change) and another (i.e. a policy change occurs). Additional scenarios can be added by assuming different levels of policy change. For each scenario, identify the expected impacts on ESs, ecosystems and stakeholder groups. Based on your findings, as well as those in the reflection points for Module 3, identify the most appropriate valuation methods for assessing ESs in this case and determine your data needs and the methodological steps you would take.

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Module 9 Final remarks

ESs contribute to human well-being – as long as the ecosystems that provide them are properly managed and conserved to sustain their supply. Policy- and decision-making processes for ecosystem management need to be properly supported by technical and scientific information derived from ecosystem assessments. Economic valuation, as part of ecosystem assessment, helps translate qualitative and quantitative information on ESs into monetary values. Valuation methods that assign monetary values to ESs have limitations; nevertheless, there is increasing recognition of the importance of economically valuing ESs.

Demonstrating and accounting for the economic contributions of ecosystems, including the ways in which they support the livelihoods of local communities, are urgently needed in Bangladesh. Economic valuation should be part of a new approach to managing ESs. Despite the limitations of such valuations, they provide essential information for sound policymaking and should be encouraged.

Decisions on whether and how to implement ES valuation should be case-specific. In some cases, economic valuation might not be feasible or convenient. If valuation is implemented, the choice of valuation method should not be done *a priori*; rather, it should be based on the aims of the study; technical, budgetary and time constraints; data quality and availability; spatial scale; and target audience. Valuation methods that rely on market values are usually easier to implement than demand-curve approaches but may be less accurate (e.g. there is a risk of overestimation when using the cost-of-substitute-goods method). Moreover, valuation methods that use market values might be unable to capture certain ESs, such as cultural ESs, and they may not allow differentiation among values attributed to single ESs or ES categories.

Credible valuation builds on robust scientific approaches. It requires, therefore, that the link between ecosystem processes and functions and the delivery of ESs is well known. This suggests the need for interdisciplinary approaches and cooperation among ecologists and economists; it might pose challenges for ESs in which multiple variables and factors are at play (e.g. water-related ESs).

Economic valuations are site-specific and highly sensitive to the methods used and assumptions made. In CBA, the choices and assumptions pertaining to discount rates and valuation periods can strongly affect results. It is advisable, therefore, to fully disclose the valuation process and to ensure that all assumptions and limitations are communicated clearly. Stakeholders should be involved in economic valuations to ensure they gain maximum insight into the importance and priorities of ESs and their perceived values.

The reliability of valuations should be ensured by the proper collection of primary data (e.g. through field activities and measurements, surveys and interviews) and the use of reliable and well-accepted secondary sources (e.g. official reports and data and robust scientific papers). Results should be tested through sensitivity analyses and other means to ensure that estimated values are as realistic as possible.

Finally, the communication of valuation results is equally as important as their calculation. People might lack confidence in economic valuations of ESs if they are uninformed about how and why the valuations were made and how they will be used.

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Annex 1 Main ES classification systems: a summary

There are many ways to classify ESs. Classification depends on the purpose it serves and may often be contentious because ecosystems are dynamic, adaptive systems with non-linear feedbacks, thresholds, hysteresis effects, and other complex features. Multiple classifications may be necessary to take into account spatial relationships between the source of an ES and the beneficiaries and the degree to which users can be excluded or can compete for the ES (Haines-Young and Potschin, 2011a). ES classification is linked to a utilitarian, anthropocentric vision, and the properties of ecosystems that people regard as useful can change over time and space, even if the ecosystems themselves remain in a relatively constant state (Costanza, 2008; Pascual and Muradian, 2010).

Table 35 summarizes the main ES classification systems, highlighting broad equivalence at the class level.[80] CICES aims to be more comprehensive than the MEA and TEEB classifications, and classification systems do not always correspond. Some categories are more general in one system than in others.

TABLE 35. **Ecosystem services classification systems and their equivalence**

Common International Classification of Ecosystem Services				MEA	TEEB
Section	Division	Group	Class		
Provisioning	Nutrition	Biomass	Cultivated crops	Food	Food
			Reared animals and their outputs		
			Wild plants, algae and their outputs		
			Wild animals and their outputs		
			Plants and algae from *in situ* aquaculture		
			Animals from *in situ* aquaculture		
		Water	Surface water for drinking	Water	Water
			Groundwater for drinking		

Table 35 continues on next page

[80] For an online tool for navigating different ES classification systems see http://openness.hugin.com/example/cices

Table 35 continued

Common International Classification of Ecosystem Services				MEA	TEEB
Section	Division	Group	Class		
Provisioning	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	Fibre, timber, ornamental, biochemical	Raw materials, medicinal resources
			Materials from plants, algae and animals for agricultural use		
			Genetic materials from all biota	Genetic materials	Genetic materials
		Water	Surface water for non-drinking purposes	Water	Water
			Groundwater for non-drinking purposes		
	Energy	Biomass-based energy sources	Plant-based resources	Fibre	Fuels and fibres
			Animal-based resources		
		Mechanical energy	Animal-based energy		
Regulating and maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by microorganisms, algae, plants and animals	Water purification and water treatment; air-quality regulation	Waste treatment (water purification); air-quality regulation
			Filtration/sequestration/storage/accumulation by microorganisms, algae, plants, and animals		
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems		
			Dilution by atmosphere, freshwater and marine ecosystems		
			Mediation of smell/noise/visual impacts		
	Mediation of flows	Mass flows	Mass stabilization and control of erosion rates	Erosion regulation	Erosion prevention
			Buffering and attenuation of mass flows		
		Liquid flows	Hydrological cycle and water flow maintenance	Water regulation	Regulation of water flows, regulation of extreme events
			Flood protection	Natural hazards regulation	
		Gaseous/air flows	Storm protection		
			Ventilation and transpiration		
	Maintenance of physical, chemical and biological conditions	Lifecycle maintenance, habitat and gene-pool protection	Pollination and seed dispersal	Pollination	Pollination
			Maintaining nursery populations and habitats		

Table 35 continues on next page

Table 35 continued

Common International Classification of Ecosystem Services				MEA	TEEB
Section	Division	Group	Class		
Regulating and maintenance	Maintenance of physical, chemical and biological conditions	Pest and disease control	Pest control	Pest regulation	Biological control
			Disease control	Disease regulation	
		Soil formation and composition	Weathering processes	Soil formation (supporting services)	Maintenance of soil fertility
			Decomposition and fixing processes		
		Water conditions	Chemical condition of fresh waters	Water regulation	Water
			Chemical condition of salt waters		
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	Atmospheric regulation	Climate regulation
			Micro and regional climate regulation	Air-quality regulation	Air-quality regulation
Cultural	Physical and intellectual interactions with ecosystems and landscapes/ seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and landscapes/ seascapes in different environmental settings	Recreation and ecotourism	Recreation and tourism
			Physical use of landscapes/ seascapes in different environmental settings		
		Intellectual and representational interactions	Scientific	Knowledge systems and educational values, cultural diversity, aesthetic values	Inspiration for culture, art and design, aesthetic information
			Educational		
			Heritage, cultural		
			Entertainment		
			Aesthetic		
	Spiritual, symbolic and other interactions with ecosystems and landscapes/ seascapes [environmental settings]	Spiritual and/or emblematic	Symbolic	Spiritual and religious values	Information and cognitive development
			Sacred and/or religious		
		Other cultural outputs	Existence		
			Bequest		

Source: CICES (2017b).

Annex 2 | Held and assigned values

The distinction between "held" and "assigned" values (Daily, 1997; Adamowicz *et al*., 1998) is crucial for understanding the valuation of ecosystem services. **Held values** represent ideals of what is desirable, how things ought to be, and how one should interact with the world (Barr *et al*., 2010). People, for example, normally value their own health, and this is a held value. People may also have held values related to environmental resources: for example, one might think that the protection and conservation of natural resources is important and desirable behaviour. **Assigned values** express the relative importance (or worth) of an object to an individual or group in a given context (Brown, 1984). It is not a characteristic of an object itself; rather, it expresses the importance of an object relative to other objects and in a given context. Assigned values depend on a number of factors, including people's perception of the object, people's own held values, and the context (e.g. in socio-economic, environmental and cultural terms). Market prices, for example, constitute an assigned value that is thought to change with market conditions. In a similar way, one might attach a certain assigned value to a forest that is better conserved and hosts a larger number of native species than another; or to water-quality A, which is better than water-quality B. The object to which the value is attached, in these cases, is the change in condition (e.g. the number of native species, or water quality). Assigned values can be influenced by held values based on morals and preferences and are less (or more slowly) transient. Broader underlying value systems may exist; for example, people may value certain forests for cultural (e.g. religious or spiritual) purposes and may be unwilling to translate these values into monetary terms. In such cases, the quantitative values assigned may be incomplete measures of the multidimensional sources of human welfare (Jones *et al*., 2016).

Annex 3 Summary of key financial formulas

Table 36 summarizes the main mathematical formulas used in valuations (and examples are given below the table). Additional formulas (e.g. single annuities) can be derived from those given. Table 36 distinguishes between:

- **single payments** – i.e. single amounts of money; and
- **series** – i.e. payments repeated over time.

Series can be further distinguished into:

- **annual series**, in which the frequency of payments is annual (i.e. the timespan between two consecutive payments such as annual fees corresponds to one year); and
- **periodic series**, in which the frequency of payments is less than annually (i.e. the timespan between two consecutive payments is more than one year, such as the costs involved in forest harvesting, which may occur only once per rotation period).

Both annual and periodic series may be either terminating (i.e. time-bounded, meaning that the series stops at a certain point) or perpetual (i.e. non time-bounded, meaning that the series is infinite).

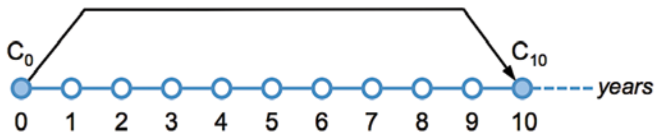
TABLE 36. **Summary of key financial mathematical formulas**

No. of payments	Frequency of payments (i.e. timespan between two consecutive payments)	Evaluation period	Time of value	Formula	Formula description
Single (single amounts)	–	Terminating	Future	$C_n = C_0\ q^n$	Future value of a single amount
			Present	$C_0 = C_n/q^n$	Present value of a single amount
Series (payments repeated over time)	Annual	Terminating	Future	$A_n = a\ [(q^n\text{-}1)/r]$	Future value of a terminating annual series
			Present	$A_0 = a\ [(q^n\text{-}1)/(rq^n)]$	Present value of a terminating annual series
		Perpetual	Future	$A_n = \infty$	*Future value of a perpetual annual series*
			Present	$A_0 = a/r$	Present value of a perpetual annual series
	Periodic	Terminating	Future	$A_{nt} = P\ [(q^{nt}\text{-}1)/(q^t\text{-}1)]$	Future value of a terminating periodic series
			Present	$A_0 = P\ [(q^{nt}\text{-}1)/(q^t\text{-}1)]\ (1/q^{nt})$	Present value of a terminating periodic series
		Perpetual	Future	$A_n = \infty$	*Future value of a perpetual periodic series*
			Present	$A_0 = P\ [(1/\ (q^t - 1)]$	Present value of a perpetual periodic series

Notations: q = (1+r); r = discount rate; n = number of years (for periodic payments = number of periodicities); a = single annuity (i.e. single annual payment); P = single periodicity (i.e. single periodic payment); t = number of years between periodic occurrences of P.

Examples

1. Future value of a single amount

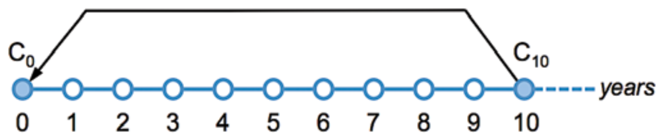


You invest USD 10 (C_0) at a discount rate (r) of 5 percent for ten years (n). The future value at year 10 (C_{10}) is:

$$C_{10} = 10\ (1+0.05)^{10}$$

$$C_{10} = USD\ 16.29$$

2. Present value of a single amount

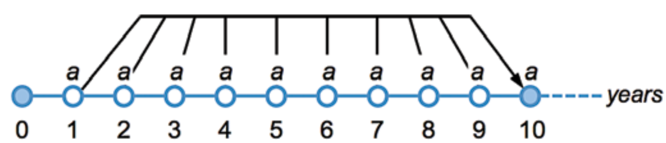


You want to obtain USD 10 (C_{10}) in ten years (n) by investing an amount C_0 at a discount rate of 5 percent (r). The amount you have to invest is:

$$C_0 = \frac{10}{(1+0.05)^{10}}$$

$$C_0 = USD\ 6.14$$

3. Future value of a terminating annual series

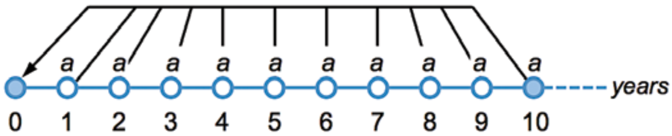


You pay an annual fishing fee (a) of USD 2 each year for ten years (n). The first payment is due at the end of the first year. Given a discount rate (r) of 5 percent, the future value after ten years (A_{10}) of all annual fishing fees paid is:

$$A_{10} = 2\ \frac{(1+0.05)^{10} - 1}{0.5}$$

$$A_{10} = USD\ 26.16$$

4. Present value of a terminating annual series

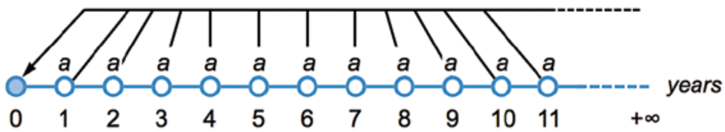


You have to pay maintenance costs (a) for forestry equipment of USD 2 per year for ten years (n). The first payment is due at the end of the first year. Given a discount rate (r) of 5 percent, the present value (A_0) of all annual maintenance payments is:

$$A_0 = 2\ \frac{(1+0.05)^{10}-1}{(0.5\ (1+0.05)^{10}}$$

$$A_0\ = USD\ 15.44$$

5. Present value of a perpetual (i.e. infinite) annual series

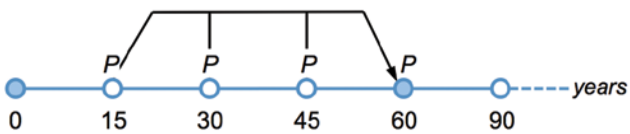


A forest is managed by harvesting the entire mean annual increment (10 m^3/ha) each year in perpetuity. Assuming a unit timber price of USD 10/m^3, which remains constant over time, the income would amount to USD 100/ha per year (a). Given a discount rate (r) of 5 percent, the present value (A_0) of the infinite series of annuities (USD 100/ha per year) is:

$$A_{10} = \frac{100}{0.05}$$

$$A_0\ = USD\ 2\ 000/ha$$

6. Future value of a terminating periodic series

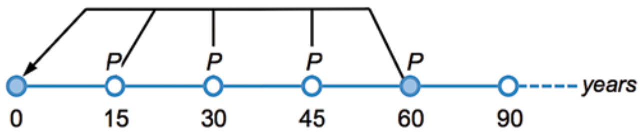


A forest concession is managed on a rotation (t) of 15 years for 60 years (i.e. 4 periods, n). Net revenues at the end of each rotation amount to USD 100/ha (P). Given a discount rate (r) of 5 percent, the future value (A_{60}) of periodic revenues over the 60-year period is:

$$A_{60} = 100 \; \frac{(1+0.05)^{60} - 1}{(1+0.05)^{15} - 1}$$

$$A_{60} = USD\ 1\ 638.59/ha$$

7. Present value of a terminating periodic series

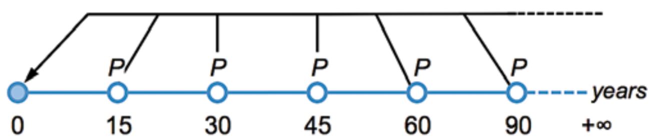


The same situation described in example 6 applies, but the forest manager wants to calculate the present value (A_0). Given a discount rate (r) of 5 percent, the present value (A_0) of the periodic revenues over the 60-year period is:

$$A_{60} = 100 \left[\frac{(1+0.05)^{60} - 1}{(1+0.05)^{15} - 1} \right] \frac{1}{(1+0.05)^{60}}$$

$$A_0 = USD\ 87.72/ha$$

8. Present value of a perpetual (i.e. infinite) periodic series



The same forest considered in examples 6 and 7 is managed in perpetuity on a 15-year rotation (t). Given a discount rate (r) of 5 percent, the present value (A_0) of the infinite series of periodic revenues (USD 100/ha) is:

$$A_0 = \frac{100}{(1+0.05)^{15} - 1}$$

$$A_0 = USD\ 92.68/ha$$

Annex 4 An example of software for cost–benefit analysis: a practical guide for users

This tool is organized into four spreadsheets corresponding with different analysis steps or levels. The spreadsheets are linked through functions. The linkages allow the automatic processing and analysis of data entered into the first spreadsheet(s) and ultimately generate analysis outputs in the last spreadsheet.

Certain organizational and practical issues are the same for all spreadsheets. **Coloured cells** (green, red or other) should be used to enter data. Red cells should be used for costs and green for revenues (or benefits). **Grey cells** should not be used or modified because they contain the formulas needed to run the tool and automatically provide outcome values.

Costs (as well as revenues) should be entered as positive values – that is, they should not be preceded by a minus sign (e.g. a cost of USD 10 should be entered as 10, not -10). It is possible to type mathematical formulas for computing values by using the normal operators (e.g. = 30+50)*50000).

The first three spreadsheets allow data to be entered to perform three types of CBA – financial, traditional and extended. The spreadsheets have similar structures based on a matrix comprising **years** (columns) **costs and revenues** (or benefits) (rows).

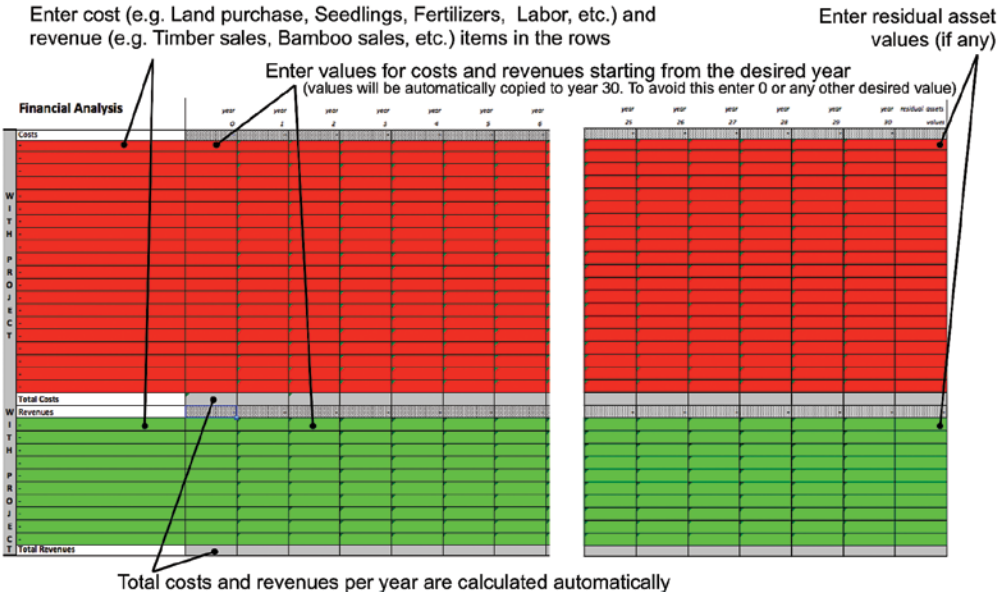
1. **Spreadsheet 1** (tabbed as **"Financial"**) enables a financial CBA to be performed (Figure 47). Columns represent years (0–30). After year 30, it is possible to report the residual (or scrap) asset value for the costs and revenues associated with a project/investment.

   When data are entered into a cell, they are copied automatically for all remaining years along the same row until year 30. This is to enable the automatic entering of data. To avoid automatic cell-filling, enter 0 (zero) or any other value you want to enter.

   Spreadsheet 1 allows analysis with or without the project. Data referring to the "with project" situation should be entered in the upper part; data referring to the "without project" situation should be entered in the lower part.

   Spreadsheet 1 allows the entry of 20 different cost items and 10 different revenue items and computes total costs and revenues automatically.

FIGURE 47
Financial spreadsheet (spreadsheet 1)



2. **Spreadsheet 2** (tabbed as **"Econ. Conventional"**; Figure 48) enables a conventional economic CBA to be performed. Cost and revenue (benefit) items entered into spreadsheet 1 are replicated automatically in the first column of spreadsheet 2. For each, conversion factors for shadow prices can be entered into the second column. If a conversion factor is entered, the corresponding data from the financial analysis (as reported in spreadsheet 1) are adjusted automatically, and the values in the cells immediately after the one reporting the conversion factor change automatically.

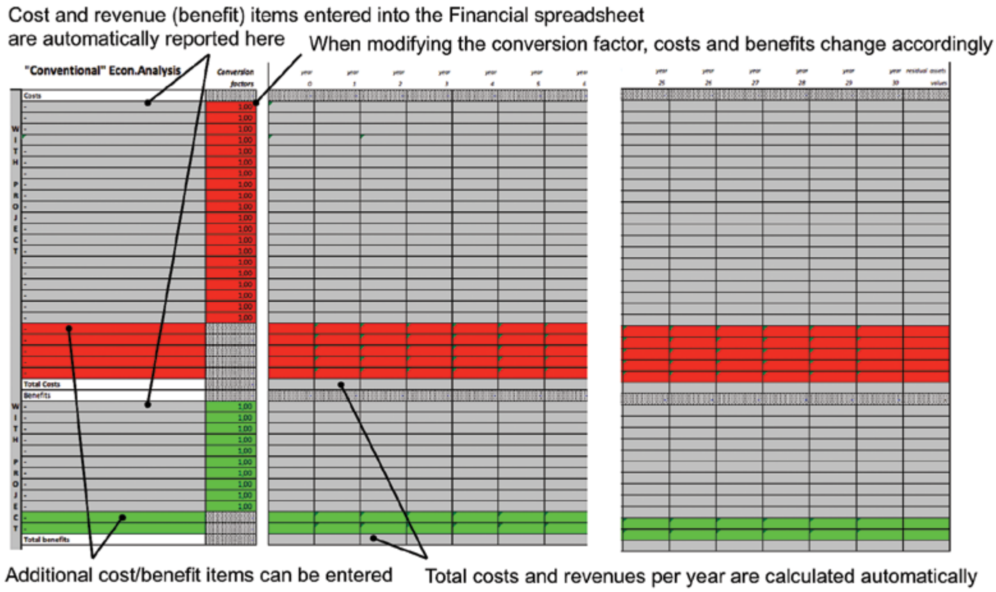
   The default value for all conversion factors is 1: if this is not modified manually, the values for costs and benefits shown in spreadsheet 2 will be the same as in spreadsheet 1. To eliminate an item, enter 0 (zero) as a conversion coefficient in the corresponding row.

   In addition to the cost and revenue items entered in spreadsheet 1, it is possible to enter new items and the corresponding values.

   As for spreadsheet 1, spreadsheet 2 is organized to perform the CBA with and without project analysis.

3. The extended economic CBA (Figure 49) can be performed in **spreadsheet** 3 (tabbed as **"Econ. Extended"**). Spreadsheet 3 has been set up to automatically visualize the sum of all cost and benefit items, as entered in spreadsheet 2 (the conventional economic CBA). It is possible to enter new items, and the corresponding values, below these values.

FIGURE 48
Conventional economic cost–benefit analysis (spreadsheet 2)



4. Once data have been entered into spreadsheets 1–3 (or at least in spreadsheet 1), **spreadsheet** 4 (tabbed as **"Results"**) reports the NPV and IRR values associated with each type of CBA (Figure 50).

   Three additional parameters are reported on the side:

   a. the discount rate, which can be modified (including to use different values for the financial and economic analyses);
   b. the timespan (number of years) of the project/investment; and
   c. the area (ha, or any other unit of area set by the user).

   All these parameters can be modified to perform sensitivity analyses and to compute any of the following six additional indicators:

   a. the B/C ratio computed according to the discount rate set by the user;
   b. the NPV computed using a rate 2 percent lower than the one set by the user;
   c. the NPV computed using a rate 2 percent higher than the one set by the user;
   d. the mean annual NPV, computed through the single annuity of a terminating annul series based on the NPV value and the timespan of the project/investment;
   e. the unit NPV per area unit (i.e. per ha or any other unit set by the user); and
   f. the mean annual NPV per unit area.

The cashflows for the three types of CBA are reported below these values. Below those, an additional table allows a visualization of the payback period based on the sum of discounted costs and revenues (benefits). The payback period can be determined as the point at which the accumulated discounted revenues (benefits) are greater than the accumulated discounted costs (i.e. their difference turns positive).

Additional sensitivity analyses can be performed by modifying data entered in one or more of spreadsheets 1–3 and observing how the indicators in spreadsheet 4 change accordingly.

Output data can be further analysed or plotted to produce charts using the functions options usually available in Microsoft Excel.

FIGURE 49
Extended economic cost–benefit analysis (spreadsheet 3)

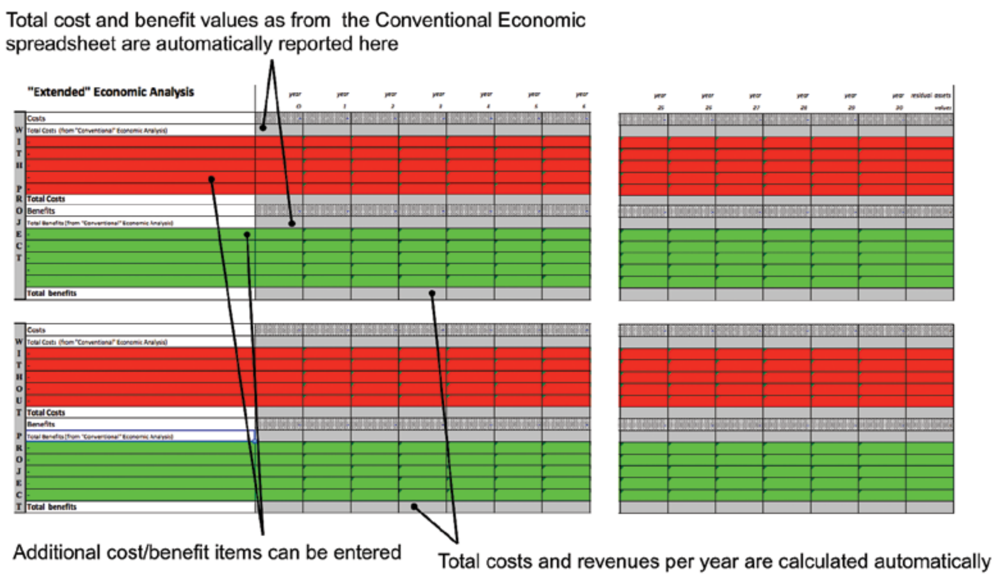
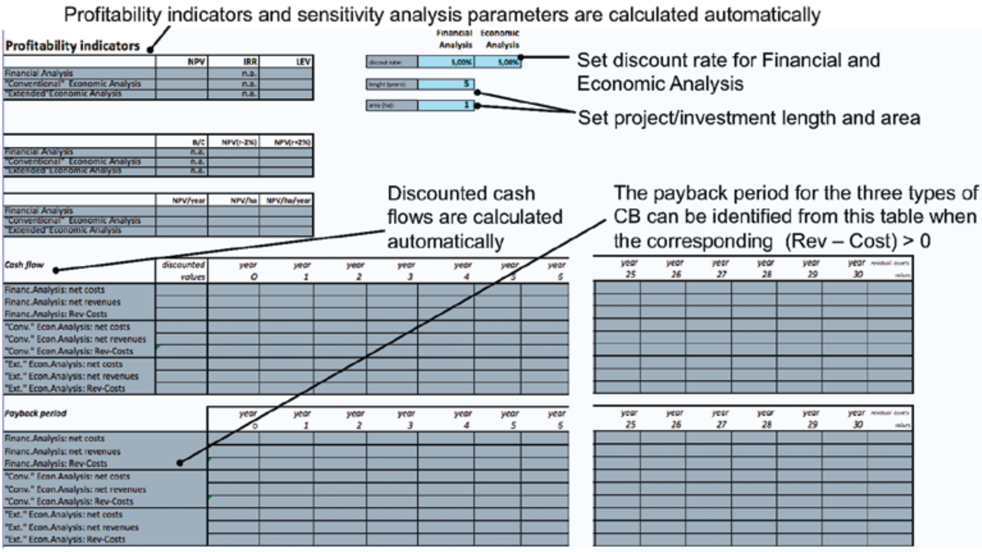


FIGURE 50
Results (spreadsheet 4)



Annex 5 Selected tools for ecosystem service assessment

Abbreviation	Tool name	Developer	Tool description and reference
ARIES	Artificial Intelligence for Ecosystem Services	Basque Centre for Climate Change (BC3)	Framework for integrating multiple modelling paradigms in the spatial modelling and mapping of ecosystem services (ESs). Supports artificial-intelligence-based data and model selection through semantic modelling to quantify ES flows from ecosystems to beneficiaries http://aries.integratedmodelling.org/
Co$ting Nature	Co$ting Nature	King's College London and AmbioTEK	Mapping and modelling tool for multiple ESs using global datasets. Quantifies ESs as opportunity costs (i.e. avoided cost of producing those ESs from non-natural capital substitutes) www.policysupport.org/costingnature
EcoMetrix	EcoMetrix	EcoMetrix Solutions Group and Parametrix	Field-based tool designed for use at relatively fine spatial scales. Primary use is to illustrate the effects of human activities (e.g. development or restoration scenarios) on ESs www.ecometrixsolutions.com/ecometrix.html
EnSym	Environmental Systems Modelling Platform	State of Victoria, Australia	Environmental-systems modelling platform for researchers to apply process-based models. Designed to provide information on how and where to invest to maximize environmental outcomes https://ensym.dse.vic.gov.au/cms/
Envision	Envision	Oregon State University	Geographic information system-based tool for scenario-based planning and environmental assessment. Enables "multi-agent" modelling to represent human decisions in landscape simulations http://envision.bioe.orst.edu/
ESR for IA	Ecosystem Services Review for Impact Assessment	World Resources Institute	Method to address project impacts and dependencies on ESs within the environmental and social impact assessment process. Identifies measures to mitigate project impacts on benefits provided by ecosystems and to manage operational dependency on ecosystems www.wri.org/publication/ecosystem-services-review-impact-assessment

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Continued

Abbreviation	Tool name	Developer	Tool description and reference
EVT	Ecosystem Valuation Toolkit	Earth Economics	Provides monetary values for natural assets under multiple modules. Includes a "researcher's library", a searchable database of ES values, and SERVES, a web-based tool for calculating ES values http://esvaluation.org/
InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs	Natural Capital Project	Spatial mapping and modelling of multiple ESs. Includes a diverse set of provisioning, regulating and cultural services from marine and terrestrial environments. Models primarily provide results in biophysical terms to which valuations can be applied www.naturalcapitalproject.org/
LUCI	Land Utilisation and Capability Indicator	Victoria University of Wellington	Explores the capability of a landscape to provide a variety of ESs. Compares the services provided by the current use of a landscape and its potential capability and uses this information to identify areas where the change or maintenance of current conditions may be most beneficial www.lucitools.org
MIMES	Multiscale Integrated Models of Ecosystem Services	Affordable Futures	Modelling platform designed to quantify causal linkages between ecosystems and the economy. Allows individuals to map decisions/ policies, and outputs illustrate how those choices affect economies and ecosystems www.afordablefutures.com/orientation-to-what-we-do/services/mimes
NAIS	Natural Assets Information System	Spatial Informatics Group	Integrated valuation database and reporting engine. Integrated with proprietary spatial modelling tools to characterize ecosystems and the flow of ESs in a landscape www.sig-gis.com/services/ecosystem-services/
SolVES	Social Values for Ecosystem Services	US Geological Survey	Spatial mapping and modelling tool primarily for quantifying cultural ESs using public participatory geographic information systems http://solves.cr.usgs.gov/
TESSA	Toolkit for Ecosystem Service Site-based Assessment	BirdLife International	Uses flow charts to describe how ESs benefit society under current conditions and alternative scenarios http://tessa.tools/

Note: This list is not comprehensive.
Source: Christin, Bagstad and Verdone (2016).

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