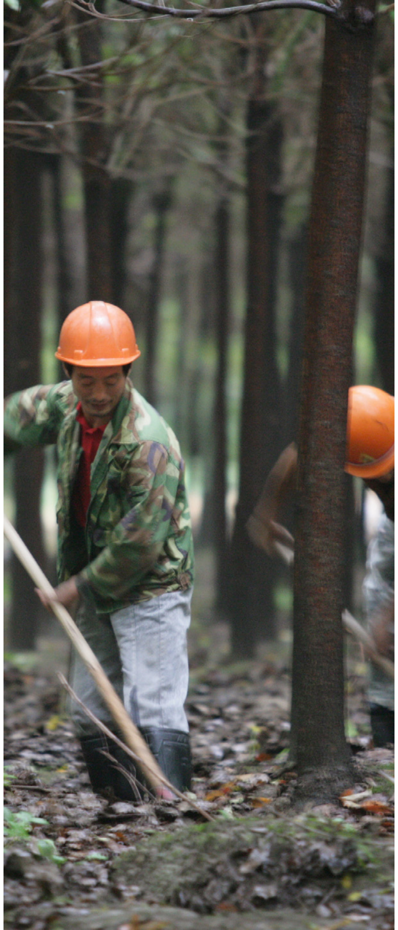



7TH WAVES ANNUAL PARTNERSHIP MEETING EDITION

Forest Accounting Sourcebook

Policy applications and basic compilation

WAVES
Wealth Accounting and the Valuation of Ecosystem Services
www.wavespartnership.org

WORLD BANK GROUP

Forest Accounting Sourcebook

Policy applications and basic compilation

WAVES

WORLD BANK GROUP

Content

Acknowledgements *vii*
Abbreviations and Acronyms *ix*

1. Introduction **1**
1.1 The importance of forests in policy-making 3
1.2 Why forests are not completely accounted for and how forest accounts can help 7
1.3 Structure of the Forest Accounting *Sourcebook* 10

PART I - Policy relevance of forest accounts **11**
2. A summary of national capital accounting for forests **11**
2.1 The need for forest accounts 11
2.2 Forest accounting solutions 12
2.3 The role of accounting 16
2.4 Experiences in natural capital accounting and forest accounting 17

3. Applications of forest accounting **21**
3.1 Environmental accounting, policy and project management 22
3.2 Policy questions 24
3.3 Policy applications of forest accounts 27
3.4 Analytical models based on forest accounting 33

PART II - Basic compilation of forest accounts **37**
4. An introduction to structuring forest accounts **37**
4.1 The need for forest accounts beyond the SNA 37
4.2 The framework for compiling forest accounts 39
4.3 Forest accounts following a resource-based approach 48
4.4 Forest accounts in the ecosystem-based approach 60
4.5 Environmental activity accounts and related flows 67
4.6 Challenges 69

5. Compiling physical accounts for forests **72**
5.1 Data sources 72
5.2 Compilation of asset accounts 80
5.3 Compiling measures of ecosystem service flows 89
5.4 Challenges 93

6. Compiling monetary accounts for forests **94**
6.1 What to value? 94
6.2 Market, quasi-market and non-market benefits 97
6.3 National accounts valuation concepts and principles 99
6.4 Methods for valuing ecosystem services and benefits 103
6.5 Valuation of forest resources and ecosystem services 107
6.6 Challenges 114

Bibliography **117**

List of Figures

Figure 1 The information pyramid 17
Figure 2 The place of environmental accounts in the information system and policy cycle 23
Figure 3 Pathways in compiling forest accounts 42
Figure 4 Scope of forest accounts in this *Sourcebook* 46
Figure 5 Typical reflectance pattern of vegetation 75
Figure 6 Methodological approaches to land cover mapping 82
Figure 7 Unsupervised classification with an arbitrarily defined five classes in a coastal region in southeastern Guatemala 83
Figure 8 Hypothetical region 84
Figure 9 Consumer surplus (A), producer surplus (B) and production costs (C) 100

List of Tables

Table 1 World Bank Group- Forest Action Plan, April 2016 5
Table 2 Coverage of accounting frameworks with respect to forests 13
Table 3 Selected policy applications of forest accounts 24
Table 4 Himachal Pradesh state income accounts and the economic contribution of forests 38
Table 5 Physical asset accounts for the area of forest and other wooded land 51
Table 6 Physical asset accounts for timber resource 53
Table 7 Monetary asset accounts for land 55
Table 8 Monetary asset account for timber resources 56
Table 9 Physical supply and use tables for timber 57
Table 10 Physical supply and use tables for wood products 58
Table 11 Basic structure of a monetary supply and use table 60
Table 12 Ecosystem extent account 62
Table 13 Measures of ecosystem condition and extent at end of accounting period. 63
Table 14 Physical flow of the supply of ecosystem services for different forest ecosystem units 65
Table 15 Supply and use of ecosystem services for a geographical aggregation 65
Table 16 Monetary ecosystem asset account 67
Table 17 Commonly used spaceborne RS data sources for vegetation studies 76
Table 18 Typical indicators and data sources for constructing the forest asset accounts 81
Table 19 General forestland asset account for a hypothetical area and one accounting period 85
Table 20 Forestland asset accounts by altitudinal range 85
Table 21 Forestland assets per grid units according to the partition presented in Figure 5.4D 86
Table 22 Parameters of forest ecosystem condition, indicators and possible data sources 87

Table 23 Indicators of forest fragmentation at the beginning and end of the accounting period for four altitudinal strata of the studied region 88
Table 24 Indicators of forest fragmentation at the beginning and end of the accounting period for different units representing grid elements in which the studied area was partitioned 89
Table 25 Typical indicators and data sources for estimating ecosystem services 90
Table 26 Overview of forest ecosystem services and benefits and their inclusion in the SNA 96
Table 27 Forest benefits and valuation techniques 107

List of Boxes

Box 1 International initiatives that can be supported by forest accounting 3
Box 2 History of SEEA 9
Box 3 Ecosystem accounting in the Philippines 15
Box 4 Accounting for Woodland in the United Kingdom 20
Box 5 Natural Resource Accounting for Indian States: Illustrating the Case of Forest Resources 29
Box 6 Guatemalan application of forest accounts 30
Box 7 Policy applications of forest accounts in WAVES countries 32
Box 8 Policy connections of forest accounts from Andalucía, Spain 33
Box 9 Scottish forestry: an input-output analysis 34
Box 10 SEEA Central Framework and SEEA Experimental Ecosystem Accounting 39
Box 11 Forestland classification in FAO Global Forest Resources Assessment 2015 43
Box 12 The boundary between cultivated and natural timber resources 49
Box 13 SEEA Central Framework Land use classification – Land use for maintenance and restoration of environmental functions 54
Box 14 Measurement approaches for provisioning services 70
Box 15 Measurement approaches for regulating services 71
Box 16 Measurement approaches for cultural services 71
Box 17 Living Standards Measurement Survey in Vietnam 80
Box 18 Calculating net present values 101

Acknowledgments

This report was written by a team led by Juan-Pablo Castañeda (World Bank) and consisting of Carl Obst (Institute for the Development of Environmental-Economic Accounting), Elsa Varela (European Forest Institute), Jose Miguel Barrios (Rafael Landívar University), and Ulf Narloch (World Bank). It benefited from contributions by David Bain and Robert Stearman (World Bank Consultants). The document builds on previous work done by Glenn-Marie Lange (World Bank); the authors are thankful for her guidance and support as WAVES Chief Technical Advisor.

The team gratefully acknowledges the peer reviewers from the World Bank: Urvashi Narain, Klas Sander, Stefanie Sieber, and Michael Vardon. The team thanks the London Group on Environmental Accounting members for all their inputs and suggestions.

Many people contributed directly or indirectly, providing comments or inputs to initial drafts. Included in this list are Sahra Abdi Nur (World Bank), Johnny Aguilar (Central Bank of Costa Rica), Birgit Altmann (United Nations Economic Commission for Latin America and the Caribbean), Cecil Bourgin (German Corporation for International Cooperation), Luz Dary Yepez (Colombia National Administrative Department of Statistics), Claudia Olarte (Colombia Institute of Hydrology, Meteorology, and Environmental Studies), Kanykey Orzobaeva (Kyrgyzstan Office of Statistics), and Renato Vargas (CHW Research). Support and guidance from the leadership team of the Environmental and Natural Resources Global Practice is acknowledged. A special thanks to Julia Bucknall, acting Senior Director, and Benoit Blarel, Practice Manager of the Public Goods Unit of the Environment and Natural Resources Global Practice. A special thank to Valerie Hickey, from the ENR Global Practice, Program Manager Eastern Europe and Central Asia. Editorial guidance was provided by Sonu Jain. Linda Starke copyedited the report.

This document was sponsored by the Wealth Accounting and the Valuation of Ecosystem Services Global Partnership (WAVES), under the leadership of Stig Johansson, WAVES Program Manager, and Glenn-Marie Lange, WAVES Chief Technical Advisor. We would like to acknowledge the financial support to WAVES from the European Commission and from the governments of Denmark, France, Germany, Japan, The Netherlands, Norway, Switzerland, and the United Kingdom.

Abbreviations and Acronyms

ARIES	Artificial Intelligence for Ecosystem Services
BSU	basic spatial unit
CEA	Classification of Environmental Activities
CGE	Computable General Equilibrium
CICES	Common International Classification of Ecosystem Services
CPC	Central Product Classification
EGSS	Statistics on the Environmental Goods and Services Sector
EPEA	Environmental Protection Expenditure Account
EU	ecosystem unit
FAO	Food and Agriculture Organization of the United Nations
FAP	Forest Action Plan
FRA	Forest Resources Assessment
GDP	gross domestic product
InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs
ISIC	International Standard Industrial Classification
LAI	Leaf Area Index
LiDAR	Light Detection and Ranging
MAES	Mapping and Assessment of Ecosystems and their Services
Mofuss	Modeling fuelwood savings scenarios
NPV	net present value
NTFP	non-timber forest product
OECD	Organisation for Economic Co-operation and Development
ONS	Office for National Statistics
PES	payments for ecosystem services
PSUT	physical supply and use tables
REDD	Reducing Emissions from Deforestation and Forest Degradation
RIOS	Resource Investment Optimization System
RS	remote sensing
SDGs	Sustainable Developments Goal
SEEA	System of Environmental-Economic Accounting

SEEA AFF	SEEA for Agriculture, Forestry and Fisheries
SEEA CF	SEEA Central Framework
SEEA EEA	SEEA Experimental Ecosystem Accounting
SNA	System of National Accounts
SolVESSocial	Values for Ecosystem Services
TEEB	The Economics of Ecosystems and Biodiversity
TOF	trees outside of forests
UNEP	United Nations Environment Programme
USLE	Universal Soil Loss Equation
WAVES	Wealth Accounting and the Valuation of Ecosystem Services
WEPP	Water Erosion Prediction Project

1. Introduction

For many countries, forests play a key role by providing incomes and livelihoods while contributing to climate change mitigation and other important ecosystem services. Taking forests into account in development planning and policy making is critical for development.

This *Forest Accounting Sourcebook* responds to an increasing demand for harmonization across countries in the creation and implementation of forest accounts. It should be especially useful for countries that have begun to compile forest accounts. The overall message of the *Sourcebook* is that forest accounts allow countries to integrate environmental data with standard economic accounting information and hence better understand the links between forests and the social and economic beneficiaries who rely on and affect those resources. This is a tool that enables countries to make better-informed decisions on the use of forest resources and to design and monitor policies that can help achieve sustainable development.

The *Sourcebook* summarizes information on forest accounting and measurement that is found in other sources. From a conceptual perspective, this includes material from the System of National Accounts (SNA) and various documents that are part of the System of Environmental-Economic Accounting (SEEA), including the SEEA Central Framework, the SEEA Experimental Ecosystem Accounting (SEEA EEA), and the SEEA for Agriculture, Forestry and Fisheries (SEEA AFF). From a compilation perspective, relevant materials that are integrated include the *Global Forest Resources Assessment* (FRA) from the Food and Agriculture Organization (FAO) of the United Nations, summaries of space-borne remote sensing databases, and materials on non-timber forest products (NTFPs) and ecosystem services.

The *Sourcebook* brings together these different materials and describes the potential of forest accounting to play a role in policy planning and review. It outlines relevant policy issues and how discussion of these issues can be supported using information from the accounts, as well as illustrating analytical extensions (such as input-output analysis and general equilibrium modeling). One feature of the *Sourcebook* is the link to examples and case studies that help describe the practical steps for overcoming common measurement issues. In this way the *Sourcebook* aims to share knowledge and to strengthen the global Natural Capital Accounting community of practitioners.

The *Sourcebook* builds on past work on forest accounts—notably, the Integrated Environmental-Economic Accounts for Forestry and the Manual for Environmental and Economic Accounts for Forestry: A Tool for Cross-sectoral Policy Analysis. In some ways, the *Sourcebook* works to reinvigorate the key issues and advice reflected in those earlier works, which remain good source material for forest accounts compilation and use. In other ways, the *Sourcebook* introduces, in a more systematic manner, recent developments in accounting for ecosystem services as well as reflecting the conceptual base provided in the standard for environmental-economic accounting, the SEEA Central Framework (SEEA CF), and the SEEA for Agriculture, Forestry and Fisheries.

The primary target audiences of the *Sourcebook* are policy makers and analysts from government agencies and ministries (data users) and agencies responsible for economic and environmental statistics (data suppliers). Other audiences include the broader research network of academics, nongovernmental organizations, and local stakeholders. It is envisioned that the *Sourcebook* can serve as a platform to enhance communication between various government agencies as well as different professional groups, including economists, foresters, ecologists, statisticians, and social scientists.

The *Sourcebook* is intended to be user-friendly and to strike a balance between describing the technical aspects of forest accounting and explaining the application of accounting to support discussion of different policy issues. The main objectives are:

- To raise awareness of the importance of forest accounting for policy planning and review
- To increase understanding of how forest accounts can help address policy questions by describing and illustrating policy applications of forest accounts (including the use of indicators and modeling applications of the accounts)
- To provide guidelines for the compilation of forest accounts in line with the standard structures, concepts, and classifications of the System of Environmental-Economic Accounting
- To provide insights into the new methods and tools for the physical measurement and valuation of relevant forest ecosystem services

The *Sourcebook* provides practical tools to aid data management and compilation according to statistical standards. Special attention is given to showing how remote sensing, spatial modeling, and statistical analysis can provide in-depth information and data to compile the accounts. An additional contribution is tackling aspects related to the measurement and valuation of forest ecosystem services.

Over time, building on the material presented here, various presentations, technical notes, case studies, policy briefs, and training materials will be developed to help countries implement and apply forest accounts. Particular areas and topics that will be a focus of further work are identified throughout the *Sourcebook*.

1.1 The importance of forests in policy making

Forests are a vital part of many countries' economies and are crucial ecosystems for creating green economies and combating climate change. Forests cover 31 percent of the global land area, and more than 1.6 billion people around the world depend on forests for various daily functions. Even though estimates of total economic contributions of forests vary widely, FAO estimates that formal forest industries account for nearly 1 percent of global gross domestic product (GDP) yearly, or more than $606 billion, and a lower-bound estimate of informal forest activity increases the total to $730 billion.[1] In addition, more than 10 million people are formally employed by the forestry sector. Although deforestation trends are declining globally, more than 13 million hectares of forests are still being lost annually through conversion or natural losses. This issue, coupled with the recognition that forests are interconnected to other sectors, has resulted in a variety of global responses that attempt to encourage sustainable forest management.[2]

To ensure that forest resources are available for future generations and that they continue to provide benefits to society, various goals, targets, and international processes have been established. Box 1 introduces some of these initiatives, including the United Nations Sustainable Development Goals (SDGs), the strategic plans under the Convention on Biological Diversity, programs on Green Growth and Green Economy, and the Reducing Emissions from Deforestation and Forest Degradation (REDD) initiative under the UN Framework Convention on Climate Change. Forest accounting can provide information to support discussion and analysis in each of these initiatives.

BOX 1: International initiatives that can be supported by forest accounting

U.N. Sustainable Development Goals

In 2000, the United Nations developed a set of Millennium Development Goals aimed at supporting development outcomes to the world's poorest populations. Forests were mentioned explicitly under Millennium Development Goal 7: "Ensuring environmental sustainability."

The UN has now completed a new process for the creation of 17 Sustainable Development Goals (SDGs) covering all countries and with a heightened coverage of environmental factors. The new goals were adopted by the UN General Assembly in September 2015. Forests are again important, especially in respect of Goal 15 "To protect, restore and

1 The FAO's *State of the World's Forests* provides an extensive discussion and assessment of the broad socioeconomic benefits of forests.

2 A recent summary of the issues is presented in Why Forests? Why Now? The Science, Economics, and Politics of Tropical Forests and Climate Change from the Center for Global Development; see www.cgdev.org/page/wfwn-paper-series.

and promote sustainable use of terrestrial ecosystems and sustainably manage forests". Forests are also of direct relevance in relation to achieving goals 2 (on food security), goal 6 (on water resources), and goal 12 (on sustainable production and consumption); and of indirect connection to many goals and targets. Information from forest accounts can be used to support reporting on progress towards these various goals. (https://www.wavespartnership.org/sites/waves/files/kc/WAVES_NCAandSDGs_Brief%20final%20web.pdf)

Convention on Biological Diversity

Under the Convention on Biological Diversity, a Strategic Plan for Biodiversity for 2011–2020 has been developed. The plan includes 20 Aichi Biodiversity Targets and provides a framework for addressing biodiversity issues. Many of the targets are related to forests, including halving deforestation and loss of other natural habitats by 2020 (Target 5) and restoring 15 percent of degraded lands by 2020 (Target 15). Furthermore, under Target 2 countries are encouraged to integrate the measurement of biodiversity into national accounting systems by 2020; the creation of forest accounts is directly relevant to this target. Overall, the targets under the Strategic Plan represent global action on protecting critical biodiversity and essential ecosystems, including forests.

Green economy and green growth initiatives

In recent years, both the U.N. Development Programme and the Organisation for Economic Co-operation and Development (OECD) have developed initiatives aimed at helping countries to achieve economic growth and development while at the same time ensuring that their environmental assets continue to provide the ecosystem services on which human well-being relies. The initiatives provide a suite of economic and environmental policy options for countries and, to support monitoring progress, a broad set of indicators has been developed. The OECD Green Growth indicator set has a broad coverage and includes an indicator on changes in the area of forestland.

UN Reducing Emissions from Deforestation and Forest Degradation programme

Since 1994, the United Nations Framework Convention on Climate Change has made key decisions and provisions for countries to mitigate climate change in the land use, land use change, and forestry sector. Reducing Emissions from Deforestation and Forest Degradation is a collaborative U.N. initiative designed to support developing countries implementing REDD+ strategies.

REDD+ is a mechanism that provides incentives to protect and sustainably manage forest resources and reduce emissions from deforestation and hence contribute to the fight against climate change. One aspect of the REDD+ mechanism is to establish a financial value for carbon stored in trees and hence recognize that forests are more valuable standing than felled. At the same time, there is recognition that the conservation of forests holds a range of other benefits for developing countries and local communities. Of relevance here is the World Bank Forest Carbon Partnership Facility (see https://www.forestcarbonpartnership.org). The 2015 Paris Agreement has reinforced the role of REDD, including an explicit call to all countries to conserve and enhance forests and other biological carbon reservoirs; through cross-referencing, past decisions on REDD+ have become part of that Agreement. This development means that forests are a clear part of the calculation in countries' nationally determined contributions (see http://www.climatefocus.com/sites/default/files/20151223%20Land%20Use%20and%20the%20Paris%20Agreement%20FIN.pdf).

A recent addition to the set of responses and initiatives that have been established to combat various forest-related issues is the World Bank Group's Forest Action Plan (FAP) for FY2016–20, which builds on and strengthens its 2002 Forest Strategy. It is beyond the scope of this Introduction to go into depth on the Forest Action Plan, but Table 1 provides a summary of the clear rationale for involvement in forest policy by the World Bank Group and its two intended focus areas. As part of the implementation of this action plan, monitoring progress and establishing the knowledge base are key areas of interest, and in this context the compilation of forest accounts may be considered an important component.

TABLE 1: World Bank Group Forest Action Plan, April 2016

Tap the potential of forests and trees to contribute to the WBG goals of ending extreme poverty and boosting shared prosperity in a sustainable manner	
Rationale for WBG Engagement	WBG Approach
Focus Area 1: Sustainable Forestry	
In many developing countries, forests support the livelihoods of hundreds of millions of people, mostly the poor and vulnerable, who are remote from market opportunities. Beyond sustaining livelihoods, sustainably managed forests also offer opportunities to lift people out of poverty where alternatives do not exist. Even in the most advanced economies, some pockets of poverty remain in forested areas.	The FAP aims to ensure that investments in the forestry sector protect and optimize the use of forests (both natural and planted) to sustain livelihoods and create jobs and economic opportunities in rural areas.
At the same time, population growth and associated changes in consumption patterns are increasing demand for forest products (wood-based energy, construction, poles, etc.) and placing more pressure on natural forests. Responding to the growing demand while preserving natural forests is an enormous challenge.	Together, the entities of the WBG are able to foster wealth generation and employment opportunities along forest-sector value chains: the World Bank can help establish investment environments conducive to small and medium-scale forest enterprises as well as large-scale investors; the International Finance Corporation can partner with responsible private sector investors to expand investment in plantations, enterprises, and value chains; and the Multilateral Investment Guarantee Agency can mitigate potential risks associated with investments in the forestry sector.
Potential Interventions under Focus Area 1	
Protect and optimize the management of natural resources through: - Participatory forest management - Sustainable management of production forests - Sustainable production of non-timber forest products - Forest biodiversity protection - Nature-based tourism Payment for Ecosystem Services	

Encourage sustainable plantations and tree planting, forests, through: - Responsible investments in large-scale commercial reforestation - Smallholder plantations and tree planting Support sustainable forest value chains, through: - Small and Medium Forest Enterprises Private investments in forest value chains	
Focus Area 2: Forest-Smart Interventions in Other Economic Sectors	
Increasing demands for food, fiber, fuel, and minerals often drive large-scale land use changes at the cost of forest and tree cover.	The WBG aims to promote interventions in other sectors (such as agriculture, hydropower, extractives, and transport) that are "forest-smart" and that consider avoiding or minimizing their potential adverse impact on forests. To do so, the WBG will aim to support clients to promote growth that does not come at the expense of their natural assets, particularly forests, and that properly values and recognizes the contribution of forest services to economies.
Addressing pressures on forests requires an integrated landscape approach, which provides the organizing principle for investing in and managing land, based on rational spatial planning and socioeconomic considerations. Forests and trees can also sustain, through the provision of ecosystem services, economic sectors such as agriculture, energy, and transport.	The WBG organizational structure, based on sectoral Global Practices and Cross-Cutting Solution Areas, can enable effective delivery of multisectoral solutions tailored to country-specific needs.
For such an approach to work, decisions on development trajectories need to be informed by comprehensive, ex-ante, and robust information on potential trade-offs for forests, as well as opportunities for restoration.	
Potential Interventions under Focus Area 2	
Support informed decision making on land uses by: Introducing forest considerations as a key element of the sustainable development agenda - Promoting land-use planning as a key tool for that purpose Deliver on forest-smart operations in sectors, such as: - Agriculture and water - Infrastructure (transport, dams and hydropower, etc.) Energy Extractive Industries	

Source: WBG 2016

In addition, many initiatives in both the public and the private sector are being established to promote legal and sustainable timber trade and the overall goal of sustainably managed forest resources. These include the Forest Law Enforcement, Governance and Trade in the European Union and certification schemes like the Forest Stewardship Council and the Programme for the Endorsement of Forest Certification. At the national level, examples worth noting include the Lacey Act in the United States and the Australian Illegal Logging Prohibition Act.

For each of these programs, an essential element is the measurement of forest resources and the monitoring of change in the forests themselves, in the associated good and services they supply, and in the impacts on economic activities and households that are connected to forests. Through detailed and integrated statistics, forest accounts can provide a more coherent set of forest-related information and indicators. Both the statistics and the associated indicators can then be used for improved management of forest resources. The compilation and subsequent use of forest accounts can help countries decide how to manage trade-offs among competing forest uses and how to design economic policy instruments (such as property rights, taxes and subsidies, and creation of markets for non-market forest services) while providing the basis for monitoring policy implementation and effectiveness. In summary, by bringing together a range of information, forest accounts can support countries in the implementation of a range of policies.

1.2 Why forests are not completely accounted for and how forest accounts can help

The System of National Accounts (SNA) is the standard international framework for the organization of economic statistics and has been adopted around the world to judge economic progress and performance. Data from national accounts, including GDP, are the primary data inputs for policy analysis, and the data figure is prominently used in many countries' decision-making processes.

While the SNA is widely adopted, it does not provide a fully integrated structure to capture the use of environmental assets and the changes in stocks of those assets. For example, cultivated and natural forests are treated as different types of assets. For cultivated forests (such as plantations) the changes in stocks and production are accounted for in an integrated way. For natural forests, however, although the income generated through timber production is accounted for in GDP, any associated capital costs (that is, depletion of natural capital) are not deducted from income. As a result, a country could deplete stocks of natural timber resources and raise GDP, but the costs of depletion would not be deducted.

In addition, as discussed at more length in Chapter 4, SNA accounts tend to only include timber production in the set of goods and services supplied by forests. Conceptually, some other goods and services should be included, such as the collection of non-timber forest products, but data on this production are limited and may be considered of small economic value. This may be particularly the case where NTFPs are collected and consumed by households or traded informally. While this activity should be recorded in GDP in theory, in practice it may be omitted or poorly measured.

Further, all national accounting in the SNA is undertaken in monetary terms. As a result, unless the information related to forests has a demonstrated economic value, generally in terms of observed market prices, there is no recording in the accounts. A necessary extension therefore is the incorporation of information on physical measures of stocks—changes in stocks and flows of all forest goods and services that support a suitably broad assessment of forests, including their depletion and degradation, in an accounting context.

The limitations of the accounting in the SNA have been recognized for many years but have gained increasing attention as awareness of the need for sustainable development has grown. Sustainable development, which has been on the forefront of multiple development agendas around the world, was defined in 1987 by the World Commission on Environment and Development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

As a contribution to the measurement of sustainable development, in the early 1990s the international statistical community started the development of extensions to the SNA (often referred to as satellite accounts) to demonstrate the potential to integrate environmental information into national accounts. These extensions were integrated in the System of Environmental-Economic Accounting released in 1993 (see Box 2). Satellite accounts are the forerunners of the forest accounts described in this *Sourcebook*.

BOX 2: History of SEEA

The potential and need to better integrate measures relating to natural capital within the national accounts framework emerged through the 1970s and 1980s and led to the release of the first (interim) SEEA in 1993. Since then there has been an important broadening of focus of the SEEA from a primary focus on extensions and adjustments to GDP and national wealth to the incorporation of accounting structures for physical information on environmental stocks and flows such as water, energy, emissions, and waste, and most recently, to the measurement of ecosystems. These three areas of the SEEA are covered through the twin publications of the SEEA Central Framework and the SEEA Experimental Ecosystem Accounting.

The SEEA Central Framework was adopted as an international statistical standard by the U.N. Statistical Commission in 2012 following a five-year revision and broad consultation process. It represents an important milestone in the advancement of natural capital accounting. With respect to forests, the SEEA Central Framework measures relevant forest areas in terms of land cover and land use as well as the stocks and changes in stocks of timber resources in both physical and monetary terms.

The SEEA EEA was endorsed by the U.N. Statistical Commission in 2013 as a starting point for countries to engage in the measurement of ecosystems and ecosystem services. It is not a statistical standard but is considered a significant synthesis of much information on ecosystem measurement. For forest accounting, the application of ecosystem accounting represents a considerable extension supporting the recording of information on provisioning, regulating, and cultural ecosystem services supplied by forests; the links to the beneficiaries of those services; and changes in the condition of forests as ecosystems rather than as stocks of timber. There are many perspectives from which to view the relationship between the environment and the economy. Consequently, there has been an ongoing release of sector- and resource-specific applications of the general SEEA framework. Examples can be found for forestry (2000), fisheries (2004), water (2012), and energy (forthcoming). A recent example currently being finalized is the SEEA for Agriculture, Forestry and Fisheries led by FAO. It has a high relevance in light of the current pressures on land use and water use and the issues of food security that affect many countries.

In addition to better accounting for natural timber resources, there is now recognition that forest ecosystems also provide non-marketed goods and services that contribute to livelihoods, but these are not usually recorded or identified in national accounts. Relevant examples of these goods and services include watershed protection, carbon sequestration, and air filtration. Nor is there is recognition of the contribution of forests to cultural and recreational benefits, including indigenous values. By not recording these types of flows, there is an underestimation of forest benefits. Consequently, many economic sectors and decision makers are not fully aware of the economic and societal dependence on forests.

In the SEEA Central Framework, the focus in relation to forest accounts is on improved accounting for timber resources, including measurement of depletion, and improved accounting for land use and land cover. Work has also been completed on an application of the SEEA CF, which includes the SEEA for Agriculture, Forestry and

Fisheries. For forestry, this incorporates material on accounting for timber resources and forestland from the SEEA Central Framework and adds-in accounting for forest product flows and inputs to forestry such as employment, capital machinery, and energy.

To address the measurement of forests as ecosystems and the associated ecosystem services, the United Nations Statistical Commission endorsed a complementary volume, SEEA EEA. This provides a framework for the integration of information on ecosystem extent, condition, and capacity as well as information on ecosystem services, in order for the data to be integrated with existing SEEA- and SNA-based information. The SEEA EEA has drawn inspiration from various nonstatistical initiatives, including the Millennium Ecosystem Assessment and the Economics of Ecosystems and Biodiversity (TEEB) study of the U.N. Environment Programme (UNEP).

1.3 Structure of the *Forest Accounting Sourcebook*

The *Sourcebook* has two main parts. Part I is aimed at potential users of forest accounts, including policy makers and analysts. Chapter 2 provides a summary of forest accounting in terms of its motivations, solutions, and experiences in different countries. Chapter 3 highlights applications of forest accounts to policy using country-level examples in order to demonstrate the potential use of accounts across a number of policy issues.

Part II is aimed at compilers of forest accounts. Chapter 4 defines the various types of accounts within the scope of forest accounting. Chapter 5 provides guidance on the data sources and methods for the compilation of accounts in physical terms, and Chapter 6 explores the concepts and methods in the valuation of forest stocks and flows. Examples and case studies are provided throughout the chapters to support understanding of the concepts and to create a benchmark for compilers of forest accounts.

PART I - Policy relevance of forest accounts

2. A summary of national capital accounting for forests

2.1 The need for forest accounts

In most countries there is information on forests in terms of the area under management for timber production or as protected areas. There may also be information on aspects such as canopy cover, species diversity, and other ecological variables. When forests are logged for timber production, there may be specific information on the volume of standing, the volume of timber harvested, and the costs and expenses of the forestry industry. In some cases there may be information on the condition of forests, such as disease or the time elapsed since natural disturbances (a fire or storm, for example).

National-level forest accounts have two objectives: providing a framework in which information on forests can be brought together to give a more complete picture of forests and ensuring that this information can be integrated within broader discussions on economic development and planning.

This second goal is often referred to as "mainstreaming." The need for mainstreaming of forest information emerges from the increasing recognition that societies and their economies have an inherent dependence on their environment and that achieving sustainable development requires more holistic and integrated ways of thinking. Natural capital accounting is a tool to support this type of approach.

Much of the established information on forests has a focus on added economic value, largely recognized in timber production. While this is very relevant, there is a need to consider forests more broadly. This is true from three main perspectives. First, ongoing timber production without consideration of the stock of timber resources and the potential for regrowth in the timber stock could lead to unsustainable levels of harvesting. An important aspect of forest accounting is thus providing definitions and approaches for the measurement of the stock of timber, its value, and—where relevant—its depletion.

Second, in many countries there is a close relationship between forests and people living nearby. The information on forests needs to encompass the variety of non-timber forest products that forests provide, including food, energy, shelter, and materials. Forest accounts should also incorporate information on the cultural connections between people and forests—for example, through measurement of cultural ecosystem services. Although the full significance of these connections is unlikely to be captured via accounting approaches, the integration of some information is needed so that these connections are better understood and included in decisions regarding forest management.

Third, over the past 15 years an increasing body of research has focused on the description and measurement of a range of regulating ecosystem services. Beyond the more commonly identified goods that are harvested from forests (timber and NTFPs) and the cultural services just noted, forests play a generally unpriced role in supplying a wide range of services of benefit to people. As noted earlier, these include regulating and filtering water flows, filtering pollutants from the air, limiting the impacts of floods and heavy rains, sequestering and storing carbon, and providing a habitat to many species, including pollinators of agricultural crops. To ensure that the contribution of forests to society is recognized as completely as possible, these regulating services should be accounted for.

2.2 Forest accounting solutions

As noted earlier, one challenge in mainstreaming information on forests and other natural resources is that the most common metric for assessing overall economic activity, GDP, does not take into account the costs of extracting natural resources in an manner that is beyond the capacity of the natural resources to sustain. This has long been recognized as a concern.

The System of Environmental-Economic Accounting organizes information in a way that the relationship between the economy and the environment can be described as completely as possible. The SEEA uses as a base the same accounting principles and measurement boundaries as applied in standard economic measurement (reflected in the SNA). By doing so, the relevant environmental information can be effectively integrated and mainstreamed.

This section describes three broad types of accounting relevant to forests that have emerged from the SNA and three SEEA frameworks: the SEEA Central Framework, SEEA AFF, and SEEA EEA. Table 2 provides an overview of the different but overlapping scopes of these frameworks.

TABLE 2: Coverage of accounting frameworks with respect to forests

Framework	Type of forest information								
	Flow of forest products		Timber resources		Economic activity connected to forestry	Forest-land	Forest condition	Forest ecosystem services	
	Physical	Monetary	Physical	Monetary				Physical	Monetary
SNA		✓		✓	✓				
SEEA CF			✓	✓	✓	✓			
SEEA AFF	✓	✓	✓	✓	✓	✓			
SEEA EEA						✓	✓	✓	✓

Accounting for timber resources and forestland

The SEEA Central Framework applies existing knowledge of natural resource accounting for timber and forestland into economic measurement and draws heavily on the measurement and definitions developed in the context of FAO's Global Forest Resources Assessment.

The SEEA CF describes standards and accounts in relation to:

- The definition of the stock of timber resources in physical terms (covering both natural and planation timber)
- Changes in that stock due to natural growth and loss, harvest, and catastrophic loss (due to storms or disease, for example)
- Approaches to the valuation of the timber stock and the measurement of depletion
- Accounting for the area of forestland and changes in its area in the context of national-level land cover and land use measurement (thus encompassing indicators for deforestation)

Overall, the approaches described in the SEEA Central Framework support the establishment of ongoing monitoring of forests and timber resources at a national level and the integration of this information into standard economic and planning discussions. Applications of these types of accounting data are described in Chapter 3.

Accounting for non-timber forest products

Integrating more-complete information on timber production and timber stocks may be considered relatively straightforward, since this activity is well known and generally appreciated. Accounting for non-timber forest products often has a much lower profile, since its economic value in terms of contribution to GDP, especially in industrial countries, may be considered small.

The appropriate framework for accounting for this non-timber activity is, in fact, the standard national accounts of the SNA. Although not commonly appreciated, the SNA includes in its scope all activity related to the collection of products from forests—whether they are ultimately sold on markets or consumed by households directly. Further, the international standards for the classification of products (CPC v2.1) and for the classification of economic activities (ISIC rev 4) both include the production of NTFPs in their scope. The measurement challenge is therefore not a conceptual one but rather one of allocating resources to the measurement of this activity.

Since the SNA and the SEEA both use standard economic classifications, they allow the integration of other related information—for example, on employment. Further, since these accounting frameworks consider both production and consumption (to ensure the accounts are balanced), it is possible to integrate information on the distribution of production and consumption—for instance, by household type and income level, or by region within a country. These types of extension may be particularly useful for the integration of information on non-timber related activity.

Accounting for ecosystem services

The most recent addition to natural capital accounting is the development of ecosystem accounting. Approaches to ecosystem accounting emerged from work on the development of the SEEA Central Framework when it was recognized that traditional approaches to natural capital accounting did not integrate information on the multiple and varied services of the environment and measures of the overall extent and condition of ecosystems.

The SEEA EEA was endorsed by the United Nations Statistical Commission in 2013. It does not represent an international statistical standard, but it does provide the initial basis for advancing this work.

Ecosystem accounting involves defining a set of ecosystems (defined as assets) across a country, each contained within a distinct spatial area. For example, at a high level a country could be divided into forests, wetlands, agricultural areas, and so on. For each ecosystem asset, the extent (area) and condition can be recorded following ecological measurement approaches that have been developed over many years, such as assessment of tree density, canopy cover, and leaf area. Declines in condition—for example, through excessive use—are considered ecosystem degradation.

In addition, ecosystem accounting records the flows of ecosystem services that each asset supplies. These services are generally put into one of three types: provisioning services (such as of food, fire, energy, water); regulating services (water flows, for instance, or climate regulation or flood control); and cultural services (such as recreation services and amenities). This breakdown builds on the Millennium Ecosystem Assessment and the TEEB study.

The ecosystem accounting framework of the SEEA places information on ecosystem assets and ecosystem services in the same context and does so in a way that supports the integration of this information with standard economic measurement. For example, a distinction is made between ecosystem services that contribute directly to current economic measures of production (such as the contribution of pollination to agriculture) and those that represent additional production and consumption (such as the filtration of air by trees). Chapter 4 provides a complete description of the ecosystem accounting model.

Accounting for ecosystem condition and services can be undertaken in non-monetary terms, but there may be cases where valuation may be appropriate. This may be challenging, since there are generally no markets in ecosystem services aside from those associated with traded goods such as timber. Without market-based prices, it is difficult to estimate values that can be readily integrated with standard economic measures. Nonetheless, a range of techniques is available and research is continuing to investigate valuation possibilities and a range of other ecosystem accounting measurement issues. Examples are discussed in Chapter 6.

Significantly, although still a developing field of measurement, a number of countries have seen the merits of the more comprehensive measurement approach described by ecosystem accounting and are involved in taking this work forward. On a national scale, ecosystem accounting work based on the SEEA EEA framework has been endorsed in Australia, Canada, Chile, Indonesia, the Netherlands, Peru, the Philippines (see Box 3), South Africa, and the United Kingdom.

BOX 3: Ecosystem accounting in the Philippines

As part of the World Bank Wealth Accounting and the Valuation of Ecosystem Services (WAVES) program, two ecosystem accounting projects have been advanced in the Philippines. The aim has been to compile pilot ecosystem accounts following the SEEA EEA for the regions of Southern Palawan and Laguna de Bay.

In Southern Palawan, a variety of accounts have been compiled as part of the ecosystem accounting exercise, spanning the years 2001 to 2014. These include accounts on land, carbon, ecosystem condition, and ecosystem services. The condition accounts have included a focus on watershed and coastal zones and included indicators of the condition of coral reefs, seagrass beds, and mangroves. A range of ecosystem services has been measured, including provisioning services such as paddy rice, coconut, oil palm, and fish and the regulating services of carbon sequestration and water regulation.

In the Laguna de Bay region, a similar approach has been followed, again with accounts spanning the years 2001 to 2014. The main accounts piloted have been those on land, water, and condition for Lake Laguna, focusing on water quality and pollutants loads. Ecosystem service flows for fish, sediment regulation, and water retention have been estimated.

The initial findings reveal that although there is a clear demand for extending the coverage and improving the data, there are clear messages about the connections that exist between economic activity and the associated ecosystems. The SEEA's ecosystem accounting approach provides a good platform for bringing relevant information together and painting coherent pictures about the trends in use of the environment.

2.3 The role of accounting

One of the challenges in making environmental information visible in economic and planning discussions is the lack of comparability and coherence between different environmental data sets, as they are often incomplete in coverage and lack a clear link to existing economic data. In this context, the SEEA-based accounting solutions just described have a number of features that make them particularly suited to the task of mainstreaming environmental information into economic and planning discussion. This section describes those features.

First, since the structure of the SEEA is aligned with the standard economic measurement framework of the SNA, environmental information can be presented alongside economic data without concern as to the comparability of the data sets. This is facilitated by the use of consistent classifications for industries and products. By way of example, the SEEA framework requires that the biophysical information concerning forestry activity (such as area, cubic meters of timber removed, and so on) aligns with the economic data (such as value added, employment).

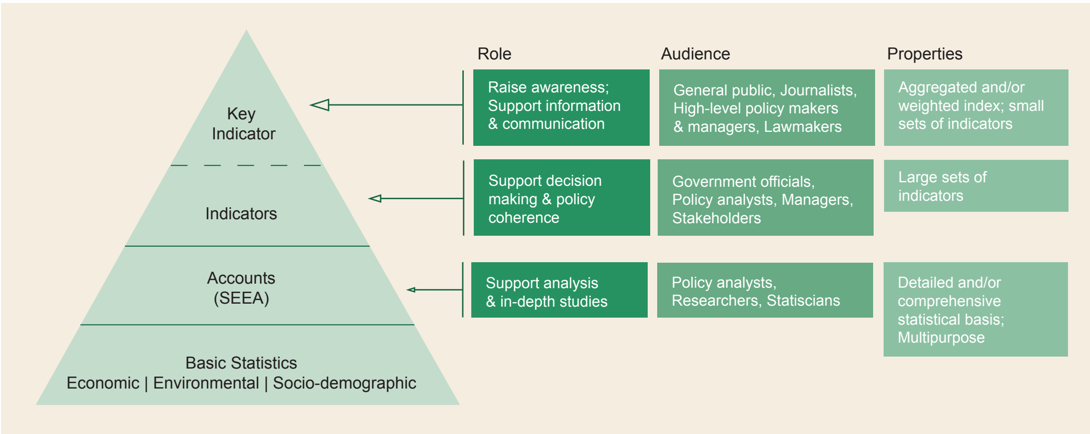
Second, the use of national-level accounting frameworks ensures broad coverage of environmental assets such that all assets (produced, non-produced, financial) can be seen in context. This means that the relative significance of changes in different assets can be assessed and that trade-offs between policies can be considered. The integration and presentation of information on different assets and activities is essential to macro-level decision-making support. For forests, this supports understanding of the connections between forestry and alternative land uses, especially agriculture, and in policy terms it can underpin the design and implementation of integrated landscape management.

Third, accounting frameworks provide a summarizing role, bringing together much existing data. Accounting frameworks therefore provide a complementary rather than competing set of data. This logic is shown in Figure 1, known as the information pyramid. It shows that accounting frameworks can provide a link between a wide range of basic data and statistics on the one hand and can aggregate indicators on the other hand.

The derivation of indicators from accounting frameworks can be particularly relevant for forests, where there is a need to understand connections between information on forest assets and the supply of goods and services. Commonly, these types of information would be found in different datasets; an accounting framework, by integrating the data in a consistent way, supports the derivation of indicators on topics such as capacity, sustainability, and productivity.

Finally, SEEA-based frameworks provide a platform and common language for discussion and exchange between agencies and different disciplines. The compilation of environmental-economic accounts requires developing relationships between different data agencies. From a user perspective, the SEEA provides a common set of terminology, language, and definitions that can facilitate understanding different perspectives on policy issues and identification of trade-offs between alternative pathways.

FIGURE 1: The information pyramid (from SEEA Applications and Extensions, Chapter 2)



2.4 Experiences in natural capital accounting and forest accounting

Global initiatives to implement natural capital accounting

The establishment of the Wealth Accounting and the Valuation of Ecosystem Services program in 2010 has added considerable momentum to the implementation of natural capital accounting at the national level. Significantly, the WAVES program has sought to move SEEA-based measurements beyond the borders of the more statistically established countries of Europe and North America and to support the process of establishing accounting work programs in Latin America, Africa, and Asia. Over 70 countries have signed up to the WAVES initiative, although implementation has focused on 8 countries: Botswana, Colombia, Costa Rica, Guatemala, Indonesia, Madagascar, the Philippines, and Rwanda. Forest accounts are considered an important objective in many of these countries.

More broadly, a global SEEA implementation strategy has been endorsed by the UN Committee of Experts in Environmental-Economic Accounting. In the context of this global strategy, various programs of SEEA implementation work are now being driven forward by the United Nations Statistics Division within the U.N. network of regional commissions, such as the United Nations Economic and Social Commission for Asia and the Pacific, United Nations Economic and

Social Commission for West Asia, United Nations Economic Commission for Latin America and the Caribbean, United Nations Economic Commission for Africa, and United Nations Economic Commission for Europe. In addition, FAO is starting to support implementation in the context of SEEA AFF.

An important role of international organizations is to support implementation and ensure appropriate guidance on specific topics and the availability of supporting documents. Through using the SEEA Central Framework as a starting point, a range of relevant materials on forest accounts have been developed. These include SEEA for Agriculture, Forestry and Fisheries, SEEA Applications and Extensions, SEEA Implementation Guide and Assessment Tools, training courses and presentations, and knowledge libraries. This *Sourcebook* complements these documents.

An important feature of the development of the SEEA has been the meetings of the London Group of Experts on Environmental-Economic Accounting. This group, which first met in 1994, has provided a forum for discussion and debate on measurement issues and has ensured an ongoing dialogue among experts at the country level. The papers and proceedings of these meetings are a valuable resource for natural capital accounting (see http://unstats.un.org/unsd/envaccounting/londongroup/).

Work in a European Union context

Building on the work of the pioneering SEEA countries, the European Union through its statistical agency, Eurostat, has established piloting programs in many areas of natural capital accounting over the last 15 years. Based on findings from these pilot programs, in recent years the Union has passed a variety of regulations and directives related to natural capital accounting. For example, in 2011 regulation No. 691/2011 requires all member states to compile data for three modules: air emission accounts, environmental taxes, and economy-wide material flow accounts;[3] additional modules on energy flows, environmental protection expenditures, and the environmental goods and services sector are also planned.

In relation to forest accounting, the European Union has been a leading player. Between 1999 and 2002 Eurostat released four studies on forest-related accounting issues, including the Integrated Environmental-Economic Accounting for Forests in 1999, a forest valuation study in 2000, a study on forest-related recreational and environmental functions in 2002, and the results of pilot studies on forest accounting in 2002.

A new European Union forest strategy was adopted in 2013. It is focused on sustainable forest management and on providing true

3 Full details on the regulation can be found at eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:192:0001:0016:EN:PDF

economic values for forest ecosystems. In addition, the strategy aims to realize forests' role in a green economy.[4] For all of the aforementioned directives and strategies, natural capital accounts can help provide systematic information and data on key resources and ecosystems for informed policy decisions. Additionally, the information garnered from accounts can help generate useful indicators for monitoring and evaluation frameworks.

Increasingly, work on ecosystem accounting is being undertaken in broader contexts. For example, under the European Union Biodiversity Strategy to 2020, action 5 calls on member states to map and assess the state of ecosystems and their services, commonly referred to as Mapping and Assessment of Ecosystems and Their Services (MAES).[5] MAES will provide key information on the status of terrestrial and marine ecosystems, and natural capital accounting can provide the link to the overall economy.

Work in the context of national statistical institutes

In the last 10-15 years, natural capital accounting has evolved from a theoretical and academic construct into a practical framework that is being applied in policy making. Many of the early efforts were focused on particular issues in specific countries and used disparate methodologies. Following the adoption of the SEEA Central Framework as an internationally agreed standard, momentum has grown for the implementation of natural capital in many countries.

Multiple countries have already established natural capital accounting programs. A recent survey by the UN Statistics Division indicated that over 70 countries either have established or are planning to establish accounting programs (see http://unstats.un.org/unsd/statcom/doc15/BG-UNCEEA.pdf).

One group of countries helped to pioneer SEEA-based accounting: Australia, Canada, Denmark, France, the Netherlands, Norway, Sweden, and the United Kingdom. In each of these countries small teams were established and maintained over time. They each released a range of different SEEA accounts and have developed relevant data sources and methods. It is due to the efforts of these countries since the 1990s that a platform exists for the implementation of SEEA today.

Advances in ecosystem accounting

In more recent years, a new wave of implementation of natural capital accounting is emerging from the development of ecosystem accounting. A number of countries are specifically focused on testing the SEEA ecosystem accounting framework (including Australia, Canada, Chile,

4 A full report on the forest strategy can be found at eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0659:FIN:en:PDF

5 For more information on MAES, see ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf

Indonesia, Mexico, and South Africa). In other cases, the SEEA ecosystem accounting framework is becoming a part of already established measurement projects. Examples include the UK National Ecosystem Assessment, the UNEP TEEB study, and work on the measurement of ecosystem services in the Netherlands at the University of Wageningen and by Conservation International in San Martin, Peru.

Forest accounting at the national level

Since the release of the first SEEA in 1993 and the development of concepts around natural resource accounting for forests, a number of countries have developed forest accounts. Examples include Australia, Canada, Finland, Guatemala, New Zealand, and the United Kingdom (see Box 4). For some of these countries the initial development has been maintained, and ongoing accounting for timber and forests takes place.

More commonly, however, forest accounting is undertaken as a one-off study. Examples include Latvia, Guyana, Tanzania, and Zimbabwe. In the latter three cases, the studies were not specifically based on the SEEA and tended to capture a broad range of forest-related goods and service flows.

BOX 4: Accounting for woodland in the United Kingdom

In November 2011, in response to the Natural Environment White Paper commitments, the U.K. Office for National Statistics (ONS) published "Towards a sustainable environment—UK Natural Capital and Ecosystem Accounting," which proposed a pilot study to produce a woodland asset account. In 2013 experimental estimates for woodland assets were developed in line with the ONS roadmap "Accounting for the value of nature in the UK," which describes the planned approach to incorporating natural capital into the UK Environmental Accounts

The ONS woodland asset accounts are based on applying the principles of the SEEA CF and the SEEA EEA. The accounts included data from 2007 to 2012 on forest condition and 12 ecosystem services. Only data in physical terms were developed for the experimental estimates, but the development of monetary estimates for ecosystem services is planned. The data showed an overall improvement in forest condition and increases in some provisioning and cultural services. Flows of carbon sequestration services declined, however.

A parallel study by ONS focused on the measurement and valuation of timber resources specifically and developed preliminary estimates for the UK for these resources of £6,870 in 2011–12. Work continues to advance the measurement of natural capital in the United Kingdom through the work of the Natural Capital Committee.

Sources: Woodland accounts from Khan, Greene & Hoo, 2013a; timber resource accounts from Khan, Greene & Hoo 2013b.

Since descriptions of forest accounts have been developed for some time, it is reasonable to consider why there are not more established national forest accounting programs, given the relevance of forest policy for many countries. A number of factors can be considered. First, traditional forest management with a focus on timber resources does not require natural capital accounting to integrate management information, and thus the benefits of compiling national-level accounts for integration with the national economic accounts are not clear. Second, while there is recognition among foresters of the relevance of ecosystem services, this is a relatively newer consideration in terms of linking to policy and management in other areas (such as agriculture), and it is certainly new for accounting frameworks. Third, implementation of accounts requires a clear commitment from users of accounting information and cannot be solely driven from the data production side. Indeed, a key aspect of current implementation programs is the engagement with users. In the past, the focus was almost solely on technical and accounting aspects.

Overall, this Sourcebook hopes to play a positive role in the current renewed push to implement natural capital accounting more generally, driven by the broad push for sustainable development–related measurement as part of the UN SDGs, the adoption of the SEEA as an international statistical standard, and long-term programs aimed at supporting the implementation of accounts such as WAVES. In this setting, additional examples and case studies of work on forest accounts are expected in the short to medium term. It is planned to ensure that these experiences and the associated lessons are shared broadly through technical notes, policy briefs, and similar materials that complement the Sourcebook.

3. Applications of forest accounting

The usefulness of forest accounts ultimately lies in the ability to use the information to inform decision making at the sectoral or national level. The forest accounts described in this Sourcebook provide integrated information to aid discussion and decision making; forest accounts do not provide the policy solutions directly.

This chapter provides an overview of the various possible applications of information from forest accounts. A key observation is that all the applications relate to a single forest accounting framework—that is, it is not necessary to create different sets of forest accounts for different policy applications. It may be that in some cases more detail is required to support analysis in particular areas, but such detail can still be placed in the context provided by a single forest accounting framework.

Three broad types of policy-related applications are described:

- Policy monitoring and indicators
- Macroeconomic and forestry sector analysis

• Integrated development and land use planning, including assessment of ecosystem services and biodiversity

There are unavoidably overlaps between these areas driven by the multifaceted role that forests play in our societies and economies. However, the different groupings help provide some sense of the variety of uses for forest accounts. The examples of applications provided here should not be considered fixed. It is likely that other uses and applications will be found as the information set becomes known and develops over time.

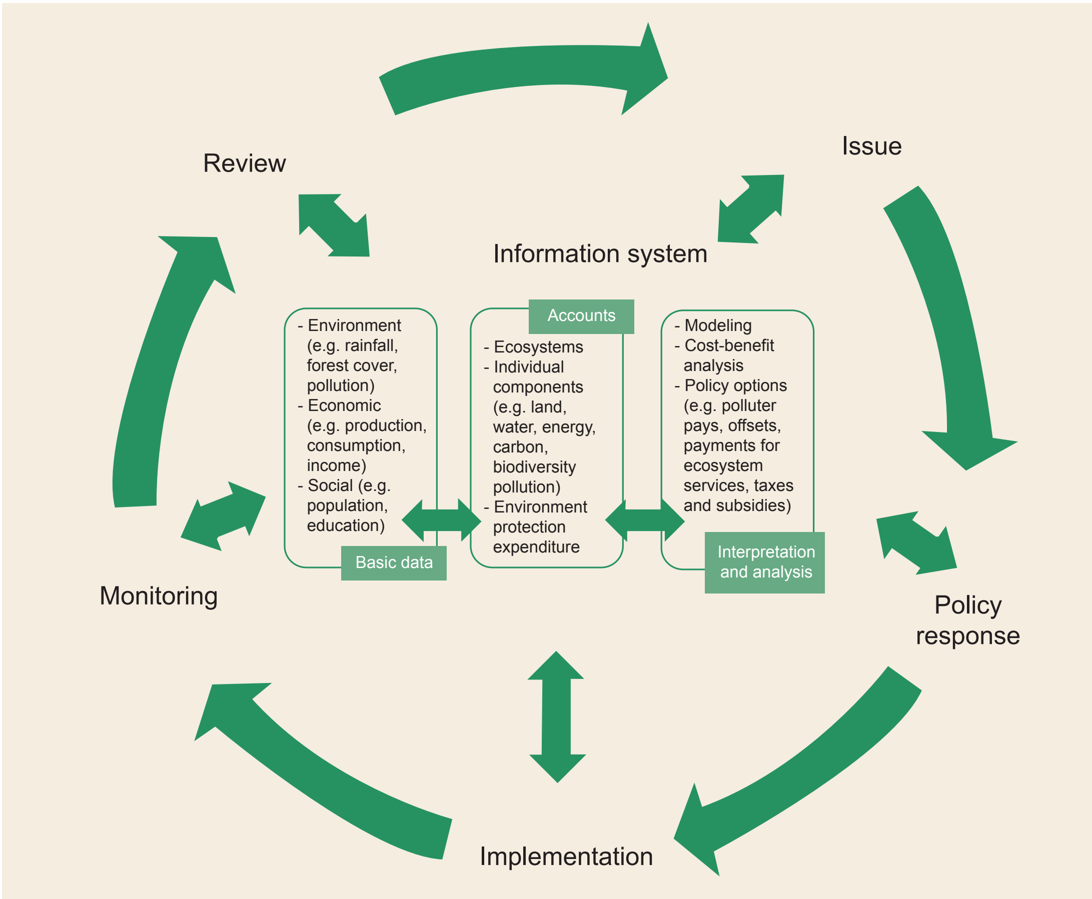
3.1 Environmental accounting, policy and project management

In general, environmental accounting and public policy or government decision making can be linked, although concrete direct examples of this have been difficult to establish. Accounts have been used in specific analyses and applications, while statistical agencies have also linked accounts to particular policy issues. Some forest-specific examples are highlighted later in this chapter.

Before discussing these examples, it is useful to understand where accounts fit into an information system used for public policy and decision making as well as identifying the likely uses and users of information. In this respect, environmental accounts are both part of a broader information system covering basic data, accounts, interpretation, and analysis, as well as feeding into the policy (see Figure 2). Decision making can occur at any stage in the policy cycle.

Hezri and Dovers identify five ways information is used: instrumentally, conceptually, tactically, symbolically, and politically. Uses of data can be categorized, according to Head, as "scientific" ("hard" data, used mainly by experts, for instance in modeling), public policy and administration (information relevant to implementation, such as used by program managers), and political.

FIGURE 2: The place of environmental accounts in the information system and policy cycle



Source: Vardon et al, 2016

Environmental accounts can be used by multiple layers of government (local, state/provincial, and national) as well as by nongovernmental actors. Accounts could facilitate polycentric governance of natural resources by allowing multiple actors (within and outside of government) to make independent decisions, informed by a single authoritative source that integrated information across levels of governance, scales, and resources (such as water, forests, and biodiversity).

Following the same type of logic as described in relation to government policy, it is possible to connect environmental accounting to the various project management cycles used at national and international levels. By way of example, the World Bank Country Partnership Framework has six main steps. At each step, accounting information is likely to be relevant, and certainly the ability to rely on consistent and coherent information at each stage in the project cycle will support the development of a shared understanding of the issues to be addressed and the effectiveness of the projects.

3.2 Policy questions

Natural capital accounts can provide improved indicators and statistics that can be used for informed policy decisions. It is useful to consider the types of problems or issues that certain countries are facing and to develop a range of relevant policy questions that help frame the issue in a way that clarifies the information requirements.

Many of the policy uses will relate to the management of resources or the development of cross-sectoral policies. In this context, the following policy questions emerge:

- What is the total economic contribution of forests and forest ecosystems, and what are the benefits from sustainable management?
- What is the distribution of benefits from forests among different groups in society?
- Is economic growth sustainable or is it based on the depletion of forests?
- What are the trade-offs among competing users, and how can resource utilization be optimized?
- What are the impacts of other sectors' policies on forests?

Is the optimal rent being generated and recovered by forest management policies; if not, are there other socioeconomic objectives that are being met, such as support to rural economies or employment creation, and what is the economic cost of meeting these other objectives?

These questions and related policy links are described further in Table 3. The intention is to give a taste of the type of issues that may be considered from the perspective of forest accounting. Given the broad coverage of forest accounting, from timber and non-timber products to ecosystem services, there are in fact few forest-related policy questions whose discussion would not be supported by the development of forest accounts.

TABLE 3: Selected policy applications of forest accounts

Indicator/ measure	Use for policy analysis	Examples of policies and actions taken from policy analysis	Type of forest accounts
1. What is the total economic contribution of forests and what are the benefits from sustainable management?			
Total value of forests including non-market forest goods and services	More comprehensive, accurate value of forests' contribution to GDP	Showing a higher value for forest contribution to GDP may increase the forestry sector's ability to request a larger share of national budget for forest management and investment	Monetary ecosystem asset accounts for forests

Value of forest services to non-forestry sectors	Measure of the economic importance of forest services to agriculture, electricity, fisheries, tourism, municipal water supply, etc.	Design economic instruments to promote sustainable forest use, for example: - Institute conservation fee on water and hydroelectricity tariffs for downstream beneficiaries that can be used for forest management or to compensate local communities - Institute tourism fees for biodiversity conservation for forest management and compensation of local communities - Negotiate international payments for carbon storage services of forests Build multisectoral stakeholder alliances on the basis of mutual benefits Identify institutional weaknesses in forest management, such as when one sector benefits but does not pay or has no say in forest management	Forest ecosystem services supply and use table; links to Input-Output tables
Value of forest goods and services used by local communities	Share of forest goods in rural livelihoods provides measure of dependence on forests of local communities	Useful for design and implementation of Payments for Ecosystem Services schemes	Forest ecosystem services supply and use table
2. What is the distribution of forest benefits among different groups in society?			
Share of forest benefits accruing to commercial, artisanal, and subsistence users of forests OR Share accruing to local, downstream, and global beneficiaries	Identify social benefits from preservation of local communities and increased equity	Identify potential conflicts, such as benefits to subsistence users/local communities being low because commercial/downstream users receive benefits Design economic instruments so that beneficiaries pay for the benefits, compensating those who may sacrifice benefits. For example, property rights, some say over how a forest is managed, and fees for environmental services received Optimize investment in forests and forest infrastructure that balances social objectives for equity and regional development as well as economic objectives of maximizing national income	Standard national accounting income and production accounts for forestry activity Forest ecosystem services supply and use table Monetary ecosystem asset accounts for forests as part of broader wealth accounts

3. Is economic growth sustainable or is it based on the depletion of forests?			
Value of forest assets and the cost of deforestation and forest degradation	Macroeconomic indicators of sustainability (such as NDP , national wealth, asset depletion)	Reassess forest management if deforestation is occurring	Timber resource asset accounts Land accounts Monetary ecosystem asset accounts for forests as part of broader wealth accounts
4. What are the trade-offs among competing users of forests?			
Value of forest goods and services under alternative forest management options	Measure economic linkages between forestry and other sectors of the economy, upstream and downstream	Optimize forest use and investment in forests and forest infrastructure by taking into account total economic value of forests, market and non-market, including linkages to non-forestry sectors and impacts on all stakeholders, economy-wide	Forest ecosystem services supply and use table
		Identify winners and losers	Monetary ecosystem asset accounts for forests
	Identify the economic trade-offs among competing sectors	Design appropriate economic instruments to achieve that strategy (fees, compensating payments, property rights, etc.)	Forestland accounts
5. What are the impacts of non-forestry policies on forest use?			
Analyze economic development scenarios that trace the full chain of causation from macroeconomic policy and/or non-forestry sector policies to their impact on forestry and land use	Measures the winners and losers, pressures on forests and forest users from alternative development strategies	Identify winners and losers.	Standard national accounting income and production accounts for forestry and other activities
	Identifies potential conflicts between development objectives of forestry and those of other sectors, such as commercial logging vs catchment protection (Ministry of Agriculture, Ministry of Energy, etc.)	Identify optimal forest management strategy, based on addressing conflicts among ministries and within a single ministry	Forest ecosystem services supply and use table
		Design appropriate economic instruments to achieve that strategy (fees, compensating payments, property rights, etc.)	

6. Is the optimal rent being generated and recovered by forest management policies; if not, are other socioeconomic objectives being met, such as support to rural economies or employment creation, and what is the economic cost of meeting these other objectives?			
Incomes that accrue to forest users, particularly the forestry industry and associated payments of resource rent	Analysis of distribution of payments of rent and understanding resource stocks and harvest rates	Setting levels of resource rent and stumpage fees, determining levels of access and harvesting regimes	Timber resource asset accounts
Estimates of broader socioeconomic benefits from forests, including employment	Understanding the full range of beneficiaries from forests and impacts of alternative forest policies	Managing trade-offs in local areas around use of forests for non-timber benefits compared with employment in timber industries	Standard national accounting income and production accounts for forestry activity Forest ecosystem services supply and use table

3.3 Policy applications of forest accounts

Policy monitoring and indicators

The use of accounting-based information for policy monitoring and the derivation of indicators is likely the most common, but sometime forgotten, role of accounting frameworks. People tend to take for granted the regular measurement of economic growth, balance of trade, corporate profits, investment flows, measures of debt, and similar indicators, but all these types of measures emerge from the compilation of regular sets of corporate and national accounts. One key ambition of the development of natural capital accounts in general and forest accounts, in particular, is the regular production of coherent information on the stock, changes in stock, and relevant flows of goods and services from environmental assets.

At an international level, an increasing number of reporting requirements are related to forest information. From a country-level perspective it would be beneficial if the relevant information could be coordinated and integrated, thus improving the quality of the information and also potentially reducing transaction costs in compiling and submitting data.

Examples of the types of international data and reporting that could be integrated within the scope of a forest accounting framework include:

- Five yearly reporting to FAO as part of the *Global Forest Resources Assessment*
- Regular reporting on the UN SDGs, in particular Goal 15 on the protection, restoration, and promotion of terrestrial ecosystems
- Reporting requirements for the Aichi targets of the Convention on Biological Diversity

- Measurement required in the context of implementation of Green Growth and Green Economy initiatives
- The compilation of estimates of greenhouse gas inventories under the UN Framework Convention on Climate Change, particularly those related to land use, land use change, and forestry

It is worth noting that each of these individual reporting requirements may well be continued without the use of forest accounts using individual data collections and processing and different definitions and classifications. The use of a forest accounting framework would support the development of an integrated database of forest-related data to provide, for a country, a coherent set of data. In the context of the international reporting requirements listed above, the focus would be on accounting for areas of forestland and, in the case of reporting to FAO, accounts for timber resources. At this stage there is no international reporting on ecosystem services.

In addition, there are international projects that are compiling estimates of wealth for all countries, where wealth is defined broadly to include natural capital. Two examples are the World Bank's estimates of comprehensive wealth and genuine savings and the United Nations Development Programme's Integrated Horticulture Development Programme inclusive wealth estimates. The development of these types of measures at the national level for forests recognizes the important role that regular monitoring of all aspects of wealth can play in understanding a country's longer-term capacity for development.

At the national level, the development of a set of forest accounts would directly support the preparation of the State of Environment reports that are legislated in many countries. As well, following the standards described in the SEEA Central Framework, it is possible to compile depletion adjusted measures of industry value added and GDP, which may provide important additional monitoring information. This specific objective of depletion-adjusted measures of economic activity is a driver of forest accounting work in India (see Box 5).

BOX 5: Natural resource accounting for Indian states: Illustrating the case of forest resources

A study released by Gundimeda et al. (2007) illustrated the potential of forest accounting to support sustainable forest management in India. The abstract to their paper published in Ecological Economics observes:

"Our main objective is to set out and apply a SEEA-based methodology to reflect the true value of forest resources in India's national and state accounts. We establish that a 'top-down' approach using available national databases is both feasible and desirable from a policy perspective. In this paper, we address four components of value creation in forests: timber production, carbon storage, fuelwood usage, and the harvesting of non-timber forest products. The results of our analysis suggest that prevailing measures of national income in India underestimate the contribution of forests to income. The income accounts of the Northeastern states in particular are significantly understated by these traditional (GDP/GSDP) measures. We are also able to identify some states which performed poorly in the context of our sustainability framework, reflecting natural capital losses due to degradation and deforestation. Our results highlight the need to integrate natural resource accounting into the national accounting framework in order to generate appropriate signals for sustainable forest management and for the conservation of forest resources which are widely used by the poor in India, as well as being significant stores of national wealth."

Since forest accounts can now be based on an agreed international standard, regular reporting will also enable a comparison across countries as to the effectiveness of various policy choices, since a common set of metrics is being compiled.

It is important that regular reporting be understood as an essential aspect of forest accounting. Too often, countries have established one-off investigations. These may be useful for considering a specific policy question at a point in time, but they do not aid the mainstreaming of forest-related information into the ongoing policy discourse. This is not to argue that very detailed accounts are required every year but rather that a program of work that ensures the compilation and publication of a core set of forest accounting information should be considered standard practice in all countries.

Macroeconomic and forestry sector analysis

A set of forest accounts can also provide a focus on direct economic-related questions relevant to forestry. Table 3 provided some examples of relevant policy questions that can be tackled using forest accounts. Forest accounts, especially ecosystem-based accounts, can identify potential conflicts regarding alternative land uses at both a national level, with respect to development objectives, and between local users of forest resources. By quantifying the relative values, trade-offs among users can be assessed and forest strategies designed that take into account all stakeholders. Forest accounts also help build multidisciplinary relationships across ministries and among different stakeholders in the private sector as people realize the extent of their dependence on forests.

Investigating these questions using a standard set of forest accounts that can be integrated with information on other economic activities is particularly useful. Indeed, an important part of the benefit of using SEEA-based accounting approaches is that the definitions and measurement boundaries have been established in a way that facilitates the integration of information.

An example that highlights this aspect of accounting is presented in Box 6, which explains the use of forest accounts to understand the dynamics of illegal logging in Guatemala. In this case the use of an accounting framework facilitated an understanding of the relevant flows and the development of policy alternatives. Regular production of accounts can then be used to monitor the effectiveness of policy implementation.

BOX 6: Guatemalan application of forest accounts

Guatemala is a small, culturally rich Central American country with a tremendous quantity of biodiversity and abundant forest resources. Like many resource-rich developing countries, Guatemala is faced with the challenge of managing its resources in a sustainable manner. Natural capita–l accounting is a tool that can provide data to inform the policy discussion surrounding natural assets. Increasing deforestation rates are a concern globally.

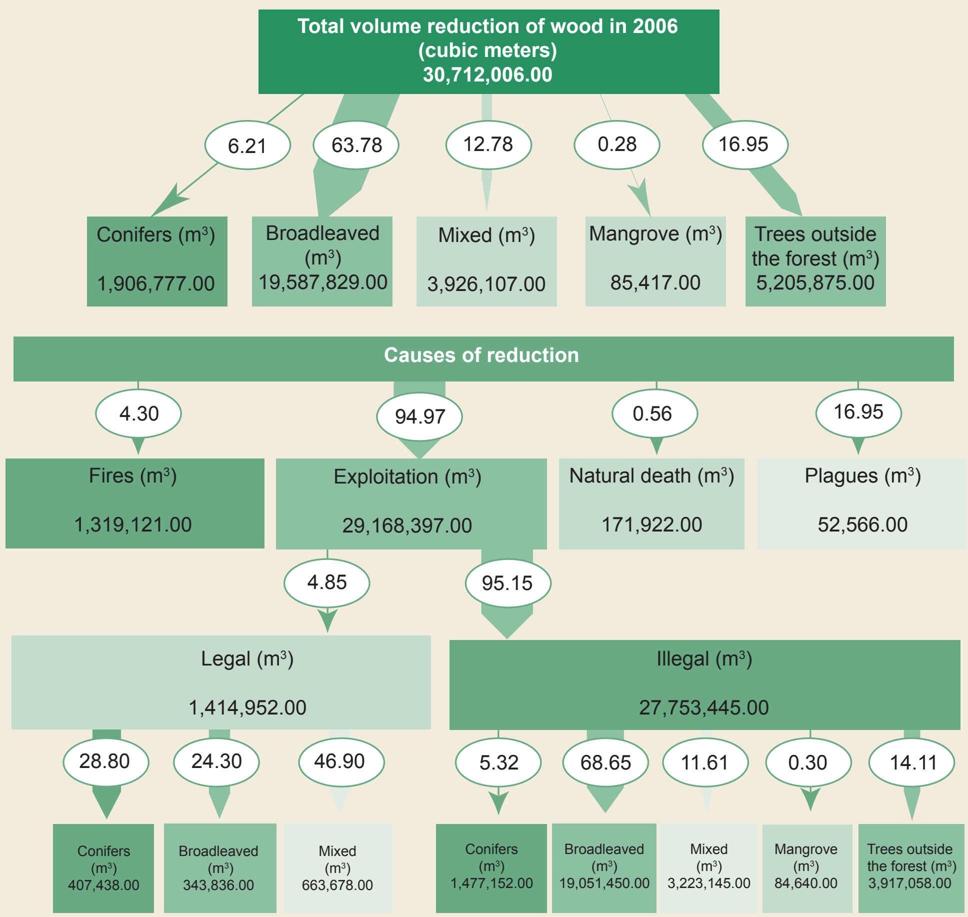
Guatemala lost a total of 106 hectares of forest cover per day between 2006 and 2010. This is equivalent to an annual deforestation rate of 1.4 percent; the deforestation rate for all of South America is 0.47 percent. Historically, illegal logging has been one of the factors in the increasing deforestation rates in Guatemala; however, the extent and perpetrators have been largely misunderstood due to calculations based on dated statistics and studies. As a result, the extent of illegal logging has been underestimated.

To more accurately understand the problem of illegal logging, academic institutions, government entities, and private organizations initiated the compilation of forest accounts according to the SEEA in 2006. Before the compilation of the accounts, the relationships in the logging supply chain were not understood. Moreover, the complete array of products and services that forests supplied were not accounted for in previous studies. As a result of the development of forest accounts, the distribution and relationship of all the actors in the logging chain are recognized and forest products are being valued more accurately. From the accounts, it became evident that illegal logging was a much larger problem than previously thought. In fact, more than 96 percent of the timber extracted from Guatemalan forests came from illegal extractions (see Figure).

The accounts also illustrated that illegal logging stems from two sectors of society: households and the private business sector. Household consumption is largely the result of the need of wood for fuel to cook and for construction materials. The private sector is represented primarily by the agriculture and timber industries. However, as the population grows and local people are increasingly living farther from forests, private sector wood brokers are relevant economic units and the clearing of forests for commercial farming is more common. Understanding the linkages and distribution of forest resources is an invaluable asset that was not available for Guatemalan policy makers before the accounts were compiled.

Prior to the compilation of the forest accounts, the National Forest Policy of Guatemala incentivized the development of a plantation silviculture industry and attempted to protect strategic forest ecosystems. Unfortunately, the policy has not curbed the problem of illegal logging and has not prevented an increase in deforestation rates. As a result of the accounts, policy makers understood more fully the flows through the entire timber sector. Thus, Guatemala is designing a new strategy to prevent illegal logging. The strategy will attempt to allow the timber industry to grow in a sustainable manner and at the same time put safeguards in place to decrease the amount of illegal logging. The objective is to provide incentives that will allow the equitable flow of benefits to all the actors in the logging chain. The development of the strategy to stop illegal logging will help Guatemala manage forest resources to contribute to the economic growth of the country while maintaining forest productivity and other environmental and community services that forests provide.

Actors, patterns, and intensity of use in the Guatemalan forestry sector



Source: Forest loss 2006–10 from INAB, CONAP, UVG, and URL and from FAO FRA 2010.

Integrated development and land use planning

This third area of policy application is one of increasing importance. The application of forest accounts in the formation of policies that reflect integrated development and land use plans is likely the most important role of accounting in the future. At the core of the policy challenge is being able to present information appropriately on the full range of economic and social benefits and costs of various policy choices. As is recognized in the broad discussion on sustainable development, for too long policies have sought to maximize only the benefits for extracting activities without appropriate balancing of other benefits that might be obtained or recognition of the costs of overharvesting. Accounting frameworks lend themselves to the coherent organization and presentation of information to support assessment of development and planning options.

Box 7 provides a number of examples of the potential for the application of forest accounts to policy in six WAVES countries. They highlight the potential breadth of the applications of forest accounts information with dimensions, including tourism, watershed management and protection, distribution of resources, coastal protection, green growth, and climate change. As the work on developing forest accounts continues in these countries, the experiences will be summarized and presented in complementary technical notes and policy briefs.

BOX 7: Policy applications of forest accounts in WAVES countries

Madagascar has a protected area network that covers 6.9 million hectares and contains significant biodiversity. The potential economic benefits from tourism and watershed protection across the network are estimated at $48 million per year; however, only $500,000 per year is being generated from tourists' visitation fees. Forest accounts are being compiled that will provide data to inform the development of a sustainable financing mechanism to be created for the national protected area network that will ensure benefits help alleviate poverty and provide equitable growth strategies for the country as a whole.

To protect Colombia's biodiversity and other forest resources and to ensure that the distribution of resources is equitable, accounts that value ecosystem services—especially those that flow from forests—are being compiled. By quantifying forest assets and constructing a supply-utilization matrix for each watershed, the country aims to reduce uncertainty about data on supply and demand of timber resources. From this information, Colombia plans to design policy mechanisms to incentivize sustainable forest management.

Only 19 percent of the land in the Philippines remains forested. To provide policy applications that will help manage competing land uses, develop sustainable forest industries, and increase benefits to local communities, the Philippines aims to compile accounts for calculation of values for all forest services. Specifically, forest accounts are being developed for mangroves to provide important information about the coastal protection, carbon sequestration, and provisioning services that mangroves provide. These data will help to inform a national development plan that emphasizes the reforestation of mangroves to provide essential coastal services to the country's inhabitants.

Costa Rica has significant areas of forest and, combined with ambitious goals for green growth, the government wants to ensure that the benefits from forest ecosystems will continue to be a source of wealth for the country. By establishing forest accounts, policy makers and the government intend to understand flows of forest ecosystem services when designing development plans, decisions on sustainable forest management, and a REDD+ strategy.

To address its vulnerability to climate change, Vietnam has enacted a Green Growth Strategy that seeks to reduce the country's greenhouse gas emissions and improve disaster preparedness plans. Forest accounts are being compiled to provide necessary data to inform policies that will incentivize the reforestation of various areas to simultaneously sequester carbon and provide erosion protection.

Botswana has experienced rapid economic growth built upon the diamond mining industry, but it now needs to diversify the country's growth path based on natural capital. By incorporating values of ecosystem services, forest accounts help inform policies to address the management of land to realize benefits from tourism while simultaneously protecting vital watersheds.

One clear message that emerges from these examples is the need for policy makers to balance competing requirements and interests. In this regard it is important to understand that the compilation of forest accounts does not advocate for a particular policy solution—accounting is, by nature, policy-neutral. The ambition is to ensure that individuals making decisions have as complete and coherent a set of information as possible. An example from Andalucía is relevant in this regard (see Box 8).

BOX 8: Policy connections of forest accounts from Andalucía, Spain

The government for the region of Andalucia in Spain is financing a study to examine various government subsidies and their contribution to the overall economy. Specifically, the study aims to answer some key questions regarding subsidies to methods that aid in avoiding forest fires. It is hoped that the study can demonstrate the value added by providing incentives to avoid forest fires. In addition, the researchers and the government want to see whether the costs incurred for environmental protection are justified. The study is using environmental and forest accounts to determine the actors and the flows of funds for the year 2010. In the future, the study and the accounts will be used to inform or modify policies surrounding the management of forests and environmental protection.

3.4 Analytical models based on forest accounting

The previous section gave a sense of the different ways in which forest accounts might support policy discussion. Often this support can be provided through the presentation of forest accounts or the derivation of indicators from the accounts. In other cases, it will be appropriate to use the information from forest accounts as inputs to analytical models. This section considers some such possible uses.

Only a short introduction to the potential modeling applications is presented here. It is envisioned that complementary technical notes providing details on the modeling applications for forest accounts will be developed in due course. It is important to note that there is an inherent connection between the development of forest accounts and the development of applications using the data. In this sense, the production of this *Sourcebook* should support advances in the compilation of accounts that can then be used to underpin modeling applications.

Physical and monetary measures from environmental accounts have frequently been used for computing environmental-economic macro-indicators and as input to economic models, such as environmental-economic Computable General Equilibrium (CGE) models and Integrated Assessment Models. Natural capital accounting information can also support the derivation of productivity measures, the analysis of supply/value chains through the economy (assessing the carbon and water embodied in traded goods, for example), and the application of CGE models.

In Box 9, forest accounts are shown to provide the data to underpin the development of macroeconomic models—in this case, an input-output model for the Scottish forestry industry.

BOX 9: Scottish forestry: an input-output analysis

Although completed some time ago, a 1999 report prepared by the Macaulay Land Use Research Institute for the Scottish Forestry Commission provides a clear example of the potential of accounting-based information to inform analysis. The report had three main objectives: to investigate backward and forward linkage effects across different forest types, to improve understanding of the contribution of the forest sector, and to assess the impacts of a number of forestry-based scenarios.

To undertake the work, the researchers conducted face-to-face interviews to provide more detailed data that supplemented general information on forestry production and industry-level information. This was brought together to form a detailed input-output table to enable analysis and modeling. An additional piece of analysis extended the input-output analysis to consider the spatial distribution of flows related to the forestry sector and hence provide a richer story.

In relation to the ecosystem services provided by forests, a variety of models can help identify the value of ecosystems and analyze trade-offs of different development schemes. For example, the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Model, developed by the Natural Capital Project, combines ecological production functions with economic valuation approaches, including market valuation, avoided costs, and production economics. This tool is free to use and scientifically viable, and it has many features that allow for flexibility. InVEST is spatially explicit, focuses on ecosystem services, details the relationships among multiple resources, and is scenario-driven.This model relies on existing knowledge, but it is modular and allows users to deal flexibly with data availability and changing knowledge.

Another tool, developed jointly by the Natural Capital Project and The Nature Conservancy, is the Resource Investment Optimization

System (RIOS), which allows users to design more-efficient water resource investments to best preserve or enhance the supply of services. RIOS combines biophysical information, information for feasible land use changes, and ecological projections of their impacts on different parts of a watershed. This model is useful for optimizing investments in a watershed and can develop investment portfolios to target different water resource objectives, including:

- Groundwater recharge enhancement
- Maintenance of base flows
- Sediment retention
- Reduce nutrient loading (nitrogen and phosphorus)
- Flood mitigation
- Biodiversity

These models can be useful in providing key information for policy makers and resource managers to sustainably manage important forest areas. Forest accounts can help to organize and make coherent the key input data and information needed to run these models. In addition, natural capital accounts can provide the information needed to run econometric models to evaluate different policy responses.

PART II - Basic compilation of forest accounts

4. An introduction to structuring forest accounts

4.1 The need for forest accounts beyond the SNA

The SNA is particularly important because the data set that it underpins constitutes the primary source of information about the economy. It is widely used for economic performance assessment, policy analysis, and decision making, and all countries are expected to compile estimates of GDP within the national accounts framework. In the SNA, all economic resources entering the economy of a country and flowing within it are assessed or estimated using the same standard concepts and definitions. Thus estimates of production, income, consumption, and investment become comparable across sectors and countries.

The way forests are considered in the measurement of GDP tends to be limited to recording the activity of the forestry industry. This activity is defined as the growing of trees, the production of timber, and the production of other forest-related products and services by economic units that specialize in these activities. However, forests also supply a range of goods and services not traded on markets, as described in Chapter 1. These goods and services have no established market price, despite their significant contribution to human well-being. The ecological and social significance of forest resources and their use also have considerable effects on other parts of the economy and public welfare and are of great political concern.

Vincent shows that frequently the industry value added, as conventionally defined, is overstated from a social standpoint, because a portion of the forestry industry's operating surplus should be attributed to the natural inputs of timber provided by forests rather than being considered a return to the investment in produced assets of the forestry industry. Further, forests provide intermediate inputs to other activities, such as livestock grazing and tourism, but the value of these inputs is not recognized. Thus, not only are the total benefits from sustainable forestry underestimated, but other economic activities are not aware of their dependence on healthy forests.

Table 4 provides a further perspective on the limitation of the scope of the SNA, showing the forest products and services that are relevant in the forests of Himachal Pradesh, India, and commenting on whether these are included in the state income accounts of the province. It demonstrates clearly that only a subset of products and services are included in standard economic measures.

TABLE 4: Himachal Pradesh state income accounts and the economic contribution of forests

Forest Product or Service		State Income Accounts (1999–2000 to 2006–07)
Industrial Wood		Depletion of forests not included in net value added or net domestic product
Fuelwood and Charcoal		NSS Consumption Expenditure Surveys (every five years) Possibly underestimated
Minor Forest Products	Resin	Production estimates from H.P. State Corporation
	Others	Only royalty value available from HP Finance Dept – Likely underestimated
Forest Services	Livestock grazing	Attributed to agriculture
	Pollination services of wild bees	Attributed to agriculture
	Recreation and tourism	Attributed to trade, hotel, and restaurant, or other services
	Carbon storage	Omitted
	Biodiversity protection	Omitted
	Soil protection	Omitted
	Water regulation	Omitted

Source: Gross State Domestic Product of HP (1999-2000 to 2006-07), Economics and Statistics Department, Government of Himachal Pradesh.

These various examples show that the usual measurement scope of GDP has a number of shortcomings regarding the treatment of forests. Hence, compiling forest accounts is useful to gain knowledge about the economic and ecological interactions between forests and society and to obtain more complete valuations (in monetary terms) for forest goods and services. These advances in information are important in underpinning improved management decisions and environmental and economic policy development.

As Lange points out, establishing a forest accounting framework paves the way for establishing a value closest to the true socioeconomic value of forests in relation to the rest of the economy. The total economic contribution of forests to the national economy could be calculated, as well as any potential losses from changes in forest use. Furthermore, the beneficiaries and their distinct nature (direct/indirect, local/downstream) could be identified. This information is necessary for optimizing forest management to support achieving economic and social objectives (such as local community preservation or increased equity).

Forest accounts provide detailed statistics that may be used in economy-wide models to assess the impacts of forestry and non-forestry policies—in particular, industrial, social, and environmental policies—and to design strategies for economic development that take into account all marketed and non-marketed goods and services provided to all stakeholders, as discussed in section 3.5.

4.2 The framework for compiling forest accounts

Environmental-economic accounts

The discussion of accounts in this *Sourcebook* follows the recommendations and treatments in the SEEA Central Framework and the SEEA EEA. In broad terms, the recommendations of the SEEA CF can be considered to reflect a resource-based approach to measurement while the SEEA EEA presents an ecosystem-based approach (see Box 10).

BOX 10: The SEEA Central Framework and SEEA Experimental Ecosystem Accounting

Initially developed in the early 1990s, the SEEA is conceived as a comprehensive approach for the organization of information concerning the relationship between the environment and the economy. To provide a suitable coverage and to ensure that more recent developments on ecosystem services could be incorporated, a two-volume approach to the development of the SEEA 2012 was applied.

The first volume, titled SEEA Central Framework, views the environment in terms of individual environmental stocks and flows and hence provides standards to account for variables such as stocks of timber, fish, mineral resources, and land and for flows of energy, water, emissions, and waste.

The second volume, titled SEEA Experimental Ecosystem Accounting, views the environment as a set of ecosystems such as forests, wetlands, grasslands, and agricultural land. The ecosystem accounting model describes measurement of the changes in the condition and extent of the stock of ecosystem "assets," measurement of the ecosystem services that flow from those assets, and the use of these ecosystem services by beneficiaries—including economic units, households, and society more broadly.

There are connections between the two volumes (for example, between the measurement of the stock of timber resources and the condition of forests). The intention is that the different perspectives are considered complementary rather than competing approaches to accounting for natural capital.

The environmental-economic accounts of the SEEA follow three main structures: physical flow accounts, asset accounts, and economic activity and transaction accounts.

Physical flow accounts[6]

In the SEEA Central Framework, physical flow accounts record the flows of materials and energy from the environment to the economy (natural inputs), within the economy (products), and between the economy and the environment (residuals). Physical flows are recorded in physical supply and use tables. These are extensions of the monetary supply and use tables used in the SNA to record flows of products in monetary terms. To align the physical and monetary tables, the International Standard Industrial Classification (ISIC) for industries and the Central Product Classification (CPC) for products are used. Generally, physical flow accounts are designed to record flows relating to a single type of material or energy, such as water, greenhouse gas emissions, or energy, and hence a single unit of measure (tons, m3, pJ, etc.) can be used. From a resource-based perspective, the forest flow accounts will focus on natural inputs from forests, the products that have a forest origin, and the use that different economic units make of them.

In the SEEA AFF, physical flow accounts are described concerning flows of timber products and NTFPs. The focus is on recording the flows of these products from the point at which they are harvested through to the immediate end-use of the products—that is, for energy, input to construction and manufacturing, and other uses. These accounts include own-account production and consumption of timber products by households.

Asset accounts [7]

Asset accounts record the opening and closing stock of an asset and the changes (additions and reductions) to the stock over an accounting period. The term stock is used to refer to the total quantity of assets at a given point in time. Asset accounts typically encompass accounts measured in both physical and monetary terms. Physical asset accounts measure the stock and its changes in appropriate physical units (such as hectares or m3). Monetary asset accounts translate the physical measurements into monetary units, generally using net present value (NPV) techniques.

Economic activity and transactions related to the environment [8]

These accounts provide an approach to highlighting relevant transactions and flows from the standard accounts defined in the SNA. Generally these transactions are not identifiable in standard presentations. The approach taken is to define the relevant activities, goods, and services that can be considered to have an environmental purpose—that is,

6 Further detail on physical flow accounts is provided in the SEEA Central Framework Chapter 3, and details on the measurement of ecosystem services is provided in SEEA EEA Chapter 3.
7 Further detail on asset accounts is provided in the SEEA Central Framework Chapter 5 and the SEEA EEA Chapter 4.
8 Further detail on accounts related to environmental transactions is provided in the SEEA Central Framework Chapter 4.

that have as their primary purpose the elimination of pressures on the environment or the more efficient use of national resources. Economic activities undertaken for environmental purposes can be separately identified and presented in functional accounts, such as environmental protection expenditure accounts.

Ecosystem services accounts

In the SEEA EEA ecosystem-based approach, the focus of physical flow accounting is on the forest ecosystem services that contribute to benefits used in economic and other human activities. In concept, ecosystem services also include non-use existence values, but the measurement of these flows is difficult. The focus of the SEEA EEA excludes service flows within and between ecosystems that relate to ongoing ecosystem processes, commonly referred to as intermediate or supporting services. While these are not included in the flow accounts, they are considered part of the measurement in the ecosystem assets (SEEA EEA 2.23). Further, the physical flow accounting in the SEEA EEA takes no explicit account of so-called ecosystem disservices, such as pests and disease. To some extent these flows will be reflected in reduced flows of some ecosystem services (for instance, lower flows of provisioning services) (SEEA EEA 2.24).[9]

Recognizing forests as environmental assets

In broad terms, assets are considered items of value for society, and in economics these have been defined as stores of value that, in many situations, also provide inputs to production processes (SEEA CF 5.1). Thus, environmental assets are defined broadly in the SEEA CF as "the naturally occurring living and non-living components of the Earth, together comprising the bio-physical environment that may provide benefits to the humanity" (SEEA CF 2.17).

The term "environmental asset" has been defined to acknowledge the value inherent in the components that constitute the environment and the inputs that the environment provides to society in general and the economy in particular.

Forests can be considered as environmental assets and measured from two perspectives: an individual resource-based perspective and an integrated ecosystem-based perspective. This *Sourcebook* encompasses both perspectives.

The resource-based perspective described in the SEEA Central Framework reflects the more traditional measurement approach in which forests are considered in terms of two primary environmental assets: forestland and timber resources.

9 Further consideration of these issues is included in the SEEA EEA Technical Recommendations (UNSD 2016).

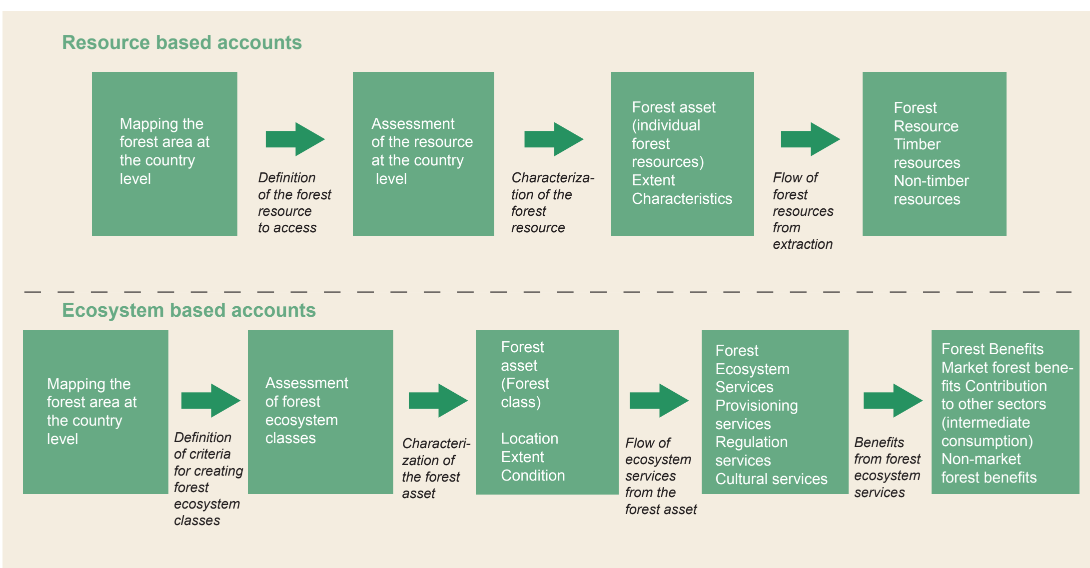
The ecosystem-based perspective described in the SEEA EEA considers forests as systems, acknowledging their role in providing a multiplicity of services that benefit society. The focus of the ecosystem-based approach is the measurement of ecosystem assets. These are defined in terms of spatial areas of similar type—for example, forests, grasslands, and mangroves. Each ecosystem asset will have a specific extent and condition that can be accounted for over time and will also supply a "basket" of ecosystem services. The aggregation of all future ecosystem services for a given basket provides, at a point in time, an estimated stock of ecosystem service flows (SEEA EEA 2.31).

Pathways in compiling forest accounts

The compilation of forest accounts following either a resource-based or ecosystem-based approach entails following a number of steps summarized in Figure 3. The departure point under either approach is the mapping of forest areas in the country or region where the accounts are to be developed. These are the land cover accounts described in the SEEA CF and the related ecosystem extent accounts described in the SEEA EEA.

FAO provides an international classification of forests and criteria to distinguish classes of forestland (see Box 11). Although countries are encouraged to follow the FAO definitions, in many cases they have developed their own definitions.

FIGURE 3: Pathways in compiling forest accounts



BOX 11: Forestland classification in FAO *Global Forest Resources Assessment 2015*

The FAO Global Forest Resource Assessment 2010 distinguishes among the following forestland classes.

Forest is defined as land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. Forestland is classified according to different types of forest. The primary distinction is between naturally regenerated forest and planted forest. It does not include land that is predominantly under agricultural or urban land use.

Naturally regenerated forest is forest predominantly composed of trees established through natural regeneration. In this context, predominantly means that the trees established through natural regeneration are expected to constitute more than 50 percent of the growing stock at maturity.

Two broad types of naturally regenerated forest are distinguished:
- Primary forest is naturally regenerated forest of native species, where there are no clearly visible indications of human activities and where the ecological processes are not significantly disturbed. Key characteristics of primary forests are that they show natural forest dynamics, such as natural tree species composition, occurrence of dead wood, natural age structure, and natural regeneration processes; that the area is large enough to maintain its natural characteristics; and that there has been no known significant human intervention or the last significant human intervention was long enough ago to have allowed the natural species composition and processes to have become re-established.

- Other naturally regenerated forest is naturally regenerated forest where there are clearly visible indications of human activities. These areas include selectively logged-over areas, areas regenerating following agricultural land use, and areas recovering from human-induced fires and so on; forests where it is not possible to distinguish whether they are planted or naturally regenerated; forests with a mix of naturally regenerated trees and planted/seeded trees where the naturally regenerated trees are expected to constitute more than 50 percent of the growing stock at stand maturity; coppice from trees established through natural regeneration; and naturally regenerated trees of introduced species.

Planted forests are predominantly composed of trees established through planting and/or deliberate seeding. "Predominantly" means that the planted/seeded trees are expected to constitute more than 50 percent of the growing stock at maturity. Planted forests include coppice from trees that were originally planted or seeded, rubberwood, cork oak, and Christmas tree plantations. They exclude self-sown trees of introduced species.

Other wooded land is land not classified as forest spanning more than 0.5 hectares and with trees higher than 5 meters and a canopy cover of 5–10 percent, or trees able to reach these thresholds or with a combined cover of shrubs, bushes, and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use.

Where possible, accounts should be compiled using these distinctions between types of forest and other wooded land. In addition, countries may be interested in compiling accounts based on the total area of different tree species.

Resource-based accounts for forests

The resource-based approach encompasses accounting for forestland and the individual resources that are obtained from forests. Typically, accounting for forestland and the stock and extraction of timber resources is the main objective, but accounting for the array of other forest products, such as cork, forest fruits, game, and fodder, can also be considered in a resource accounting framework. The relevant accounts and entries are described in the SEEA Central Framework and the SEEA AFF.

The first step to compiling the accounts starts from defining and mapping the forest area in the country. This can be the compilation of a land cover account that will count all land in a country—forests, grassland, wetlands, agricultural and urban areas, etc. This account will form the basis for accounting for forestland and for defining the resources to be assessed within the forest area. Considering timber as an example, timber resources in areas identified as forests should be measured according to the main relevant characteristics (for example, broad-leaved and conifer species or age classes) and according to the main accounting classes (such as cultivated and natural classes) in the appropriate physical units for this resource (generally cubic meters). The next step is to calculate the flow of these resources to the economic units that benefit from their extraction. These flows are the basis for the monetary accounts. It is noted that within a resource-based approach, countries with timber resources outside forest areas (in orchards, for instance) can also be recorded.

Ecosystem-based accounts for forests

The ecosystem-based approach focuses on measuring the contributions of the ecosystems to the economy and to society more broadly, as described in the SEEA EEA. For this purpose, using spatial areas as the units of analysis is most appropriate. As in the resource-based accounts, the first step is to map the forest area in the country. This is followed by defining a set of criteria that allow creation of homogenous forest ecosystem units (EUs) (for example, based on vegetation type). According to these criteria, the forest EU will be classified into different forest classes. These forest EUs will be the ecosystem assets that provide flows of ecosystem services to society.

Once the forests assets have been delineated, the next step is to describe their location, extent, condition, and capacity to supply ecosystem services. The condition of these forest assets will be described through key characteristics. Basic characteristics are those related to the ecological nature of the ecosystem units in terms of species composition, structure, and key ecological processes. Example indicators include measures of tree density, canopy cover, and species diversity; other proposals are noted in Chapter 5. A list of key characteristics of the forest assets should be selected, together with associated indicators of changes in those characteristics. The indicators should be responsive to changes in the functioning and the integrity of the ecosystem.

Asset characterization forms the basis to move to the next step, when the flow of ecosystem services from these assets to society is measured. Ecosystem services are classified into three main groups: provisioning services (biomass for timber, for example), regulating services (such as air filtration), and cultural services (for instance, recreational opportunities). The benefits obtained from forest assets can either enter into the market directly (such as through the harvest and sale of timber), contribute to the production of private benefits in other sectors (for example, through the value added earned by recreation-based companies), or generate benefits to society that are not traded in the markets (such as through the supply of cleaner air).

Similarities and differences between resource-based and ecosystem-based accounts

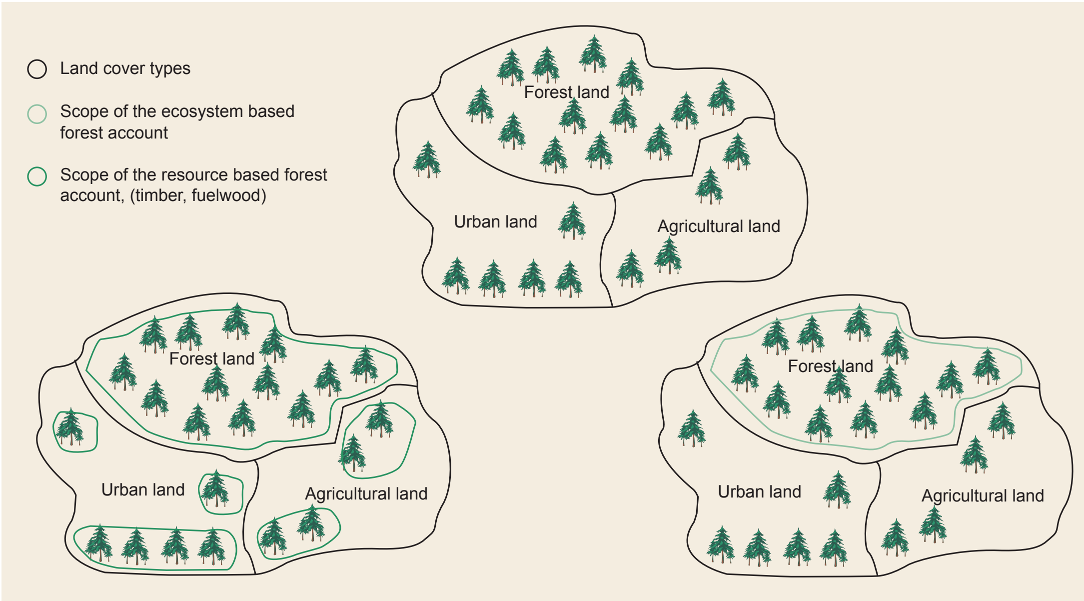
The two approaches are related, as they both start from measurement of the forest area in a country and they both assess forests following an accounting logic. But while ecosystem-based accounting focuses on forest ecosystems in terms of spatial areas, the resource-based approach focuses on individual components such as timber.

Nevertheless, the information compiled for individual resources included in the resource-based approach, such as timber or extent of forest cover, will be a useful input in the assessment of the flow ecosystem services. Thus, timber resources are included in ecosystem accounting, reflecting the main provisioning services provided by forests. Most likely these will flow to the economy as benefits traded in markets. Further, measuring changes in the stock of timber resources and the area of forestland via resource-based asset accounts is likely to provide an indication of pressures on ecosystem condition.

While there is a common starting point for measurement for both approaches, there are some similarities and differences in scope that are represented schematically in Figure 4. The key points include the following:

- Land accounts will use as their starting point all types of land—forest, urban, agricultural, etc.
- Accounts for forestland will not incorporate all potential timber resources but they should incorporate areas of forest that are not used for timber production either because they are protected areas or because they are too remote to be economically viable.
- Concerning ecosystem services, a resource-based approach will include only provisioning services, primarily timber, whereas an ecosystem-based approach will also incorporate regulating and cultural services.

FIGURE 4: Scope of the forest accounts in this *Sourcebook*



Trees outside of forests

In some countries, there may be a significant use of trees outside of forests (TOF). In these cases it will be insufficient for policy and analytical purposes to consider only forest areas in terms of understanding the supply, use, and sustainability of timber resources. Conceptually, both resource-based and ecosystem-based accounts are relevant in assessing TOF.

In a resource-based account, since the focus is on timber resources irrespective of location, the same logic used for physical flow and assets accounts can be applied—but with the inclusion of TOF. This will likely raise some different measurement challenges.[10] But to understand the overall supply and demand for timber within a country or region, excluding these timber resources would be a limitation and, indeed, would likely yield misleading results.

In an ecosystem-based approach, ideally the development of ecosystem accounts would be undertaken for a range of ecosystem types, not only forested areas. That is, ecosystem extent and condition accounts would cover an entire country or region of interest, and measurement of ecosystem services would involve recording flows of different services across different ecosystem types. With this potential in mind, accounting for TOF is a matter of identifying the ecosystem types that have trees but are not considered forest ecosystems—such as other wooded land (following FAO), scrub-covered areas, or agricultural land, including orchards and agro-forestry systems. For these non-forest ecosystem types, the relevance of the trees would be captured in the measurement

10 One challenge is the likelihood that the growth and yield of timber resources from TOF will be different from trees inside forest areas.

of ecosystem services that may cover timber, water flow regulation, soil retention, and air filtration, for example.

Overall, while the focus of the *Sourcebook* is on accounting for forest areas, the accounting approaches described here can be adapted to incorporate TOF. In this sense it is important when designing accounts that the measurement scope is defined appropriately to the policy questions and environmental reality. A complementary technical note on accounting for TOF is planned.

Key concepts for environmental-economic accounting for forests

Economic units

An institutional unit is an economic entity that is capable, in its own right, of owning assets, incurring liabilities, and engaging in transactions and other economic activities with other entities (SEEA CF 2.110). Groupings of institutional units that are similar in their purposes, objectives, and behaviors are defined as institutional sectors. The environmental accounts typically consider four environmental sectors: households, corporations, general government, and non-profit institutions serving households. These sectors are of particular interest in the ownership of forest resources and ecosystems.

Groupings of institutional units that undertake similar types of productive activity are referred to as industries. In forest accounts, the key grouping is the forestry industry, which encompasses activities related to the management of forest, the cultivation and harvest of timber, and a range of associated activities. However, a range of other industries will also be relevant, depending on the activities associated with a forest area and the services provided by forests. Possibilities include the agricultural industry, the recreation and tourism industry, and the water supply industry. The analysis of the institutional units linked to forest ecosystems and resources is of particular interest for predictions on the expected flow of forest ecosystem services.

In the national accounts and in the SEEA, an economy is defined in reference to the set of economic units resident within a geographic boundary (or economic territory) of a country. By convention, all land—including forestland—is considered to be owned by a resident economic unit. If a foreign economic unit—one based in another economic territory—owns land, then it is considered to be purely a financial relationship; the land itself remains an asset of the country in which it is located. Any associated production from that land is also considered the production of the country in which the land is located.

The production boundary

In accounting terms, the economy is represented by both stocks and flows. Measurement of flows centers on three economic activities: production, consumption, and accumulation. Among these, production is the most significant measurement boundary. All products (goods and services) that are regarded as produced through a combination of labor and capital are considered to be within the production boundary. This set of goods and services also defines the set of goods and services that must be consumed or accumulated and defines the scope of measures of GDP. Flows between the economy and the environment are estimated in relation to the production boundary as defined in the SNA. This aspect is further developed in the asset section.

Depletion and degradation

Depletion is the decrease in quantity of the stock of a natural resource over an accounting period that is due to the extraction of the resource by economic units occurring at a level greater than that of regeneration (see SEEA CF 5.76 and 5.4.2 for a detailed discussion). It relates to the decline of an individual resource. In general, depletion will be recorded when the rate of resource extraction surpasses the annual growth (for instance, mean annual increment). It thus aligns well with the concept of sustainable yield in silviculture. Typically, depletion is assessed within a resource-based perspective.

Ecosystem degradation relates to the decline, due to human activity, in the condition of an ecosystem asset that is also reflected in a decline in the capacity of that asset to provide a basket of ecosystem services in a sustainable manner. Attributing declines in condition to human activity is not straightforward and may be a mixture of direct and indirect effects. Further, because the focus in ecosystem accounting is on multiple ecosystem services, it may well be that some human activities lead to increases in some ecosystem services at the expense of supplying other ecosystem services. Thus, the trade-off between the future supply of the total basket will need to be assessed when measuring ecosystem degradation.

4.3 Forest accounts following a resource-based approach

In resource-based accounts of forests, the different forest resources are accounted for individually, resource by resource. Traditionally, timber and forestland are the two environmental assets considered. In recent years, forest accounts are also beginning to consider stocks and flows of carbon. Forests also produce a number of resources that the resource accounts should record when relevant. For example, the vast array of non-wood forest products, such as cork, berries, mushrooms, game, or honey. Although practical examples in this *Sourcebook* concern timber and forestland, the methodology is generally applicable to accounting for other resources.

The physical asset accounts in a resource-based approach record all the environmental assets of that particular type, even if they are not currently expected to deliver benefits to an economic owner. In monetary terms, however, the conceptual scope of the resource-based assessment is limited to those parts of the assets that have an economic value. For example, the physical asset accounts for timber resources should include all timber resources in a country, whereas the monetary asset accounts may exclude some resources such as remote forests, since there may be no current economic value associated with the stock of timber.

The boundary between cultivated and natural resources

A key issue in setting up a resource-based accounting framework for forests is consideration of the boundary between cultivated and natural resources. This distinction is based on the extent to which there is active management over the growth of the resource (SEEA CF 5.24) (see Box 12).

One outcome of the treatment is that since the growth of natural timber resources is not considered production on an ongoing basis, there may be misleading economic signals about changes in a natural forest. That is, income from overexploitation is recorded as part of GDP, but the corresponding depletion of the forest stocks would not be recorded as a cost against income. The SEEA Central Framework addresses this issue by defining clearly measures of depletion of biological resources, including timber, and showing how the cost of depletion can be allocated against the income of extracting economic units.

BOX 12: The boundary between cultivated and natural timber resources

The SEEA Central Framework differentiates cultivated and natural timber resources to enable alignment with the SNA production boundary. In the SNA a distinction is made in the treatment of biological resources between those whose growth is relatively highly managed (such as livestock and orchards) and those whose growth has a low level of human inputs. This distinction can also be applied to timber resources. Note that this treatment does not relate to the tree species or ecological features of timber resources.

Cultivated timber resources are those grown under management practices that constitute a process of economic production. These practices should be significant relative to the value of timber resources and should be directly connected with the growth of the timber resources.

Examples of management practices include control of regeneration (seeding, planting of saplings) and regular supervision of the trees to remove weeds or attend to pests. It should be the case that the process of production is one that is classified as forestry activity following ISIC Division B.

Control over harvesting is not sufficient to establish that a timber resource is cultivated. If it were, any legislation controlling the use of virgin forests would be sufficient to cause a designation of "cultivated."

Natural timber resources are these that are not under regular management practices. In the accounts, the growth of cultivated resources is considered to take place within the production boundary. The growth of the trees is recorded on an ongoing basis as production and, at the same time, as an increase in inventories/work-in-progress of those enterprises undertaking the cultivation. Subsequently, when the cultivated timber is harvested/logged, a decrease in timber inventories is recorded together with an equivalent amount of sales.

The growth of natural timber resources, in contrast, is not considered to take place within the production boundary. These resources enter the production boundary only at the time the trees are harvested.

For all biological resources, making the distinction between natural and cultivated resources may be difficult, and conventions may need to be applied. For forestry, because management practices are likely to vary considerably across and within countries, no general rules for the allocation of timber resources between these two classes can be determined. On the contrary, the countries should determine the status of their timber resources based on the criteria just described. This process generally starts with the delimitation of the production boundary for the different land classes where the timber resources grow.

Physical resource–based asset accounts

Forestland asset accounts

Physical asset accounts for land (land accounts) describe the area of land and changes in the area of land over an accounting period. Land accounts can be developed for land use, land cover, or land ownership classes (that is, according to ownership by industry or institutional sectors). The concepts of land cover and land use are separate but interrelated. Sometimes the relationship is clear, such as for the land cover class crops where the use is agriculture. At other times, however, land use and land cover cannot be inferred from each other. For example, for the land cover of forests, the land use may be for timber production, for recreation, or for maintenance of water supply. With data structured in an accounting format, it is possible to link land cover to land use, including presenting matrices showing the changes in land cover and land use over an accounting period.

Land accounts can be constructed for forest and other wooded land. Forestland accounts and timber resource asset accounts have a different focus but are related, since in most countries the majority of timber resources are found in areas of forest and other wooded land. At the same time, the scope of the accounts may be different, since there are timber resources outside of areas of forest and other wooded land and also areas for forest that are not used for timber resources (such as protected areas).

An initial step in compiling accounts is to define the scope of the forest and other wooded land accounts. A standard approach is to define the forestland classes consistently with the definition in the FAO Forest Resource Assessment 2010 (see Box 11 earlier in this chapter), which is also included in the SEEA Central Framework.

Table 5 presents a physical asset account for forest and other wooded land. It shows the opening and closing stock by area and type of forest and the changes in the stock. Countries can further divide the forestland classes to distinguish relevant details (such as conifer, broad-leaved, or mixed forestland).

There are different additions and reductions in stock that should be recorded following the SEEA Central Framework (CF 5.291–5.294). Afforestation and natural expansion represent additions to the stock. Afforestation represents an increase in the stock of forest and other wooded land due to either the establishment of new forest on land that was previously not classified as forestland or silvicultural measures such as planting and seeding. Natural expansion is an increase in area resulting from natural seeding, sprouting, suckering, or layering.

Deforestation or natural regression can cause reductions in the stock. Deforestation represents a decrease in the stock of forest and other wooded land due to the complete loss of tree cover and transfer of forestland to other uses. Natural regression should be recorded when the stock of forest and other wooded land reduces for natural reasons.

TABLE 5: Physical asset accounts for the area of forest and other wooded land (hectares)

	Type of forest and other wooded land				
	Primary forest	Other naturally regenerated forest	Planted forest	Other wooded land	Total
Opening stock of forest and other wooded land					
Additions to stock					
Afforestation					
Natural expansion					
Total additions to stock					
Reductions in stock					
Deforestation					
Natural regression					
Total reductions in stock					
Closing stock of forest and other wooded land					

Source: SEEA Central Framework Table 5.15.

Timber resources asset account

The timber resources asset account records the volume of timber resources at both the beginning and end of an accounting period and the change in the stock during that period. A basic structure of a physical asset account for timber resources is presented in Table 6.This structure can be expanded by countries to increase the informative potential of their accounts, for example by including information on important species of tree. This general accounting structure can also be used to record other relevant forest resources such as rubber, game, or berries.

In Table 6 timber resources are initially classified as either cultivated or natural (see Box 11 earlier in this chapter for details). To support analysis, natural timber resources are further divided, depending on their availability for wood supply. Timber may not be available to be felled for wood supply due to physical, economic, or regulatory reasons. The category "not available for wood supply" includes timber in remote areas where logging operations are not economically viable due to physical constraints or long distances between the forest and the place of use. In addition, timber resources in protected areas where logging is prohibited, such as national parks, should be included in this category. This may be most relevant to understanding the significance of protected areas or remote forests.

Timber resources not available for wood supply are within the scope of the resource-based account in physical terms. However, since these resources have no market value, no monetary values are recorded in accordance with the valuation principles of the SNA and the SEEA Central Framework.

Timber resources are defined in the SEEA Central Framework following the definition in the FAO *Global Forest Resources Assessment* 2010. Timber resources are defined by the volume of trees, living or dead, and include all trees regardless of diameter, tops of stems, large branches, and dead trees lying on the ground that can still be used for timber or fuel.

The volume should be measured as the stem volume over bark at a minimum breast height from the ground level or stump height up to the top (SEEA CF 5.350). If a different definition is used at the country level, countries should make this clear to enable comparisons among regions. It is also important to maintain the use of a single definition to support time series analysis.

Timber resource accounts should also include, where relevant, resources found in areas not classified as forestland, such as orchards or along roadsides.

TABLE 6: Physical asset accounts for timber resources (cubic meters over bark)

	Type of timber resource		
	Cultivated timber resources	Natural timber resources	
		Available for wood supply	Not available for wood supply
Opening stock of timber resources			
Additions to stock			
Natural growth			
Reclassifications			
Total additions to stock			
Reductions in stock			
Removals			
Natural losses			
Catastrophic losses			
Reclassifications			
Total reductions in stock			
Closing stock of timber resources			

Source: SEEA Central Framework Table 5.19.

The main additions to the stock of timber resources are annual growth and reclassifications. The SEEA Central Framework refers to the gross increment as annual growth—that is, the volume of increment over the period of reference trees with no minimum diameter. It applies to the trees that were already in the opening stock. Increases in the area of forest, other wooded, or other areas of land that lead to an increase in timber resources are recorded under reclassifications. Also, reclassifications may be due to shifts in the resources already recorded in the opening stock due to changes in the management practices (such as moving from natural to cultivated). The main reductions in the stock are due to removals, losses, and reclassifications. Removals are estimated as the volume of timber resources removed from forestland, other wooded land, and other land areas during the accounting period. They include removals of trees felled in earlier periods and of trees killed or damaged by natural causes. Felling residues arise because, at the time of felling, a certain volume of timber resources is rotten, damaged, or considered excess in terms of the size requirements.

Natural losses are the losses to the growing stock (that is, living, standing trees) during an accounting period due to mortality from causes other than felling. Examples include losses due to natural mortality, insect attack, fire, wind throw, or other physical damages. Catastrophic losses represent exceptional and significant losses due to natural causes. The volume of natural losses and catastrophic losses should only be recorded against these categories when there is no possibility that the timber resource can be removed. Countries should decide on the criteria to classify their losses as either catastrophic or natural.

Monetary resource–based asset accounts

Forestland asset account in monetary terms

The physical asset accounts for forest and other wooded land are part of the general land accounts. Since the value of land is likely to be most related to its use rather than its land cover, it is likely to be necessary to cross-classify categories of land cover (particularly tree-covered areas) by categories of land use. The most common land uses for tree-covered areas are agriculture, forestry, maintenance and restoration of environmental functions, and land that is not in use. For the purposes of this *Sourcebook* we consider that the estimate of the value of agricultural land with tree cover is not in scope.

Most forest and other wooded land is classified under the land use "forestry." Some forest and other wooded land can be subject to protection, as defined by the International Union for Conservation of Nature (see Box 13). This land should be put in the category "land used for maintenance and restoration of environmental functions." Finally, land with no clearly visible indications of human activities should be classified as land not in use. This would be the case where timber resources are not available for wood supply or there are primary forests that do not supply identified goods or services—that is, they are subject neither to management practices nor to legal protection and they do not play any policy-assigned role in biodiversity preservation or in the protection of human assets.

BOX 13: SEEA Central Framework land use classification—land use for maintenance and restoration of environmental functions

This class includes protected areas as defined by the International Union for Conservation of Nature—that is, clearly defined geographical spaces recognized, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values. Protected areas should aim, where appropriate, to:

- Conserve significant landscape features, geomorphology, and geology
- Provide regulatory ecosystem services, including buffering against the impacts of climate change
- Conserve natural and scenic areas of national and international significance for cultural, spiritual, and scientific purposes
- Deliver benefits to resident and local communities consistent with the other objectives of management
- Deliver recreational benefits consistent with the other objectives of management
- Facilitate low-impact scientific research activities and ecological monitoring related to and consistent with the values of the protected area
- Use adaptive management strategies to improve management effectiveness and governance quality over time
- Help to provide educational opportunities (including as regards management approaches)
- Help to develop public support for protection

Changes in the ownership of land between institutional sectors can be detailed if monitoring these changes is of interest in the country.

Table 7 shows the monetary asset accounts for land. The cells in grey show the classes where forestland is most likely to be recorded. The opening value of the stock of forestland corresponds to the sum of the values of the forestland (by type of land use) at the opening date, using the opening land prices and land areas in each category. Land values may vary significantly across a country depending on the land's accessibility as well as physical and regulatory constraints on its uses.

Most physical changes in forestland concern the reclassification of land uses between agriculture, forestry, built-up, and protected areas. Within the reclassification cells, the values given will correspond to the value of the reclassified pieces of land as estimated at the opening of the stock in the opening category. Revaluations include the change in value of land between the opening and closing of the accounting period that are due solely to changes in price.

TABLE 7: Monetary asset accounts for land (currency units)

	Type of land use							
	Land used for agriculture	Land used for forestry	Land used for aqua-culture	Use of built up and related areas	Land used for maintenance & restoration of environmental functions	Other uses of land n.e.c.	Land not in use	Inland water
Opening value of stock of land								
Additions to stock								
Acquisitions of land								
Reclassifications								
Total additions to stock								
Reductions in stock								
Disposals of land								
Reclassifications								
Total reductions in stock								
Revaluations								
Closing value of stock of land								

Source: SEEA Central Framework Table 5.16.

Timber resources asset account in monetary terms

The monetary asset account for timber resources in Table 8 follows the same structure as the physical asset account for timber resources. However, timber not available for wood supply is not included in these accounts. That part of the timber resource will not be harvested because of legal or economic reasons. Therefore, no monetary returns are expected and the value of timber not available for wood supply equals zero by definition.

The values of the opening and closing stock of timber resources will most commonly be estimated as the net present value of future flows of income from timber extraction. The estimation of NPVs for timber is discussed further in Chapter 6 and at more length in SEEA Central Framework section 5.8. Trends in harvest intensity and prices used to estimate the opening and the closing values will affect the NPV-based estimates. The valuation of the flows of timber resources should be based on the same prices that underpin the valuation of the opening and closing stock. The aim is to measure the changes in the stock, in situ, before extraction.

Catastrophic losses require a particular treatment since the resource might be only partly affected. The remaining value of the trees salvaged after storms (deducting the possible losses in quality) should be accounted for in removals, if removed. Similarly, the catastrophic losses only include the reduction in value of trees that have died after an event such as fire.

Changes in the monetary asset are related not only to physical fluxes of timber resources but also to changes in the present value of each unit of these resources, including changes in prices and in the structure and composition of the resource. The changes are reflected as reclassifications or revaluations.

TABLE 8: Monetary asset account for timber resources (currency units)

	Type of timber resources	
	Cultivated timber resources	Natural timber resources available for wood supply
Opening stock of timber resources		
Additions to stock		
Natural growth		
Reclassifications		
Total additions to stock		
Reductions in stock		
Removals		
Natural losses		
Catastrophic losses		
Reclassifications		
Total reductions in stock		
Closing stock of timber resources		

Source: SEEA Central Framework Table 5.20.

Flow accounts in the resource-based approach

Physical flow accounts

Forest resources can be recorded in physical flow accounts as materials (such as timber or NTFPs) or measured in terms of natural inputs of energy (such as fuelwood)—see, for example, SEEA Central Framework Table 3.5. The resource-based flow accounts are aligned with the production boundary of the SNA.

Physical supply and use tables (PSUT) can focus on two main aspects. In Table 9, the PSUT follows timber products from forests to the point of further processing into timber products. This Table highlights the link between timber products and the growth, felling, and removal of timber. It has been developed in the context of the SEEA for Agriculture, Forestry and Fisheries.

TABLE 9: Physical supply and use tables for timber

Supply table	Output			Total output	Imports	Total supply
	Forestry activity (ISIC 021)	Loggins activity (ISIC 022)	Other in-dustries			
Products						
Net annual increment						
Gross fellings						
Felling residues (not removed)						
Removals (over bark)						
Bark						
Removals (under bark)						
Roundwood (under bark) on which industrial round-wood						
Wood fuel						

Use table	Intermediate Consumption			Household final consumption		Gross fixed capital formation	Charges in inven-tories	Exports	Total use
	Logging industry	Manu-facturing industry	Generation of energy products	Energy	Other uses				
Products									
Net annual increment									
Bark									
Roundwood (under bark) on which industrial roundwood									
Wood fuel									

Source: FAO (2016) SEEA Agriculture, Forestry and Fisheries

In Table 10 the focus is on the origin of different forest products, the processing of raw forest products into other products such as sawnwood and firewood, and the use of each product by different industries in the economy as well as final users (including households, government, capital formation, and exports). From these tables, commodity balances for forest products may be constructed, as well as input-output tables and social accounting matrices in which the production of forest products is represented in physical terms. Such tables can be expanded to include other forest resources.

TABLE 10: Physical supply and use tables for timber

	Output by industry									
Supply	Forestry & logging	Wood products	Pulp	Paper	Printing	Recycling	Others	Total ind. supply	Imports	Total supply
Standing timber	95,920							95,920		95,920
Sawn logs	23,162							23,162	1,451	24,613
Firewood	31,200							31,200	27	31,227
Pulpwood	11,869							11,869	699	12568
Wood and wood products		13,017						13,017	3,490	16,507
Paper pulp			2,591					2,591	2,212	4,803
Paper				9,602				9,602	5,612	15,214
Wood waste as product		8,152						8,152	686	8,838
Paper waste as product					5,066			5,066	1,238	6,304
Non-timber forest products							x	x		x
Forest services							x	x		x

	Intermediate consumption by industry								Final users			
Use	Forestry & logging	Wood pro-ducts	Pulp	Paper	Print-ing	Recy-cling	Others	Total ind.	Con-sumption	Capital forma-tion	Ex-ports	Total use
Standing timber	66,232							66,232		29,688		95,920
Sawn logs		23,337						23,337			1,275	24,613
Fire-wood							2,423	2,423	28,429		375	31,227
Pulp-wood			10,944					10,944			1,624	12,568
Wood and wood products		7,736					6,076	13,812			2,695	16,507
Paper pulp				4,372				4,372			431	4,803
Paper							4,465	4,465			4,167	8,632
Wood waste as product		2,265	2,162				3,431	7,858			980	8,838
Paper waste as prod-uct				5,276				5,276			1,028	6,304
Non-timber forest prod-ucts												
Forest services												

Source: Eurostat 2002a, Table 61, p. 65

Monetary flow accounts

Monetary supply–use tables record all flows of products in an economy between different economic units in monetary terms. They describe the structure of an economy and the level of economic activity. These tables are already in the SNA, and forest products can be tracked within them, although it may be necessary to disaggregate the standard classifications of products to provide the appropriate level of detail.

As shown in Table 11, which presents a stylized monetary supply and use table, these flows are classified by type of product in the rows and by type of economic unit (enterprises, households, government) and the rest of the world in the columns. Enterprises are classified to industries based on their principal activity. An exception to this is the column titled "Accumulation." Accumulation flows are recorded separately since, while they concern supply in the current accounting period, they are not used in the current period and instead accumulate for future use or sale by economic units and the rest of the world—in the form of either inventories or fixed assets.

TABLE 11: Basic structure of a monetary supply and use table

	Industries	Households	Government	Accumulation	Rest of the world	Total
Supply table						
Products	Output				Imports	Total supply
Use table						
Products	Intermediate consumption	Household final consumption expenditure	Government final consumption expenditure	Gross capital formation (inclu-ding changes in inventories)	Exports	Total use
	Value added					

Source: SEEA Central Framework Table 2.1.

4.4 Forest accounts in the ecosystem-based approach

In the ecosystem-based approach of the SEEA EEA, ecosystem assets are represented in terms of spatial areas that contain a combination of biotic and abiotic components and other characteristics that function together (SEEA EEA 4.1). Forests ecosystems can therefore be considered ecosystem assets.

Strictly speaking, ecosystems cannot be defined in terms of mutually exclusive spatial areas. However, for accounting purposes there must be clear boundaries for ecosystems such that all ecosystems across a country can be covered without gaps or overlaps.

In response to the accounting need for spatial units, the SEEA EEA and subsequent advice has developed a "units model" that describes three different but connected types of spatial area that are relevant for accounting purposes. At the lowest level is the basic spatial unit (BSU), which is most commonly considered a small grid square (ideally between 10 and 100 square meters). Each BSU will have some particular characteristics, including slope, altitude, vegetation, etc.

Groupings of similar, contiguous BSU form an ecosystem unit.[11] Depending on the number of characteristics taken into account, there will be small or large numbers of different types of EU. One possibility is that only land cover is taken into account. Then, at a high level, there may be around 15 types of EU—including, for example, tree-covered areas. Conceptually, individual EUs are likely to represent the statistical approximation to ecosystems as commonly conceived.

For accounting and analytical purposes, it will be most common to record information about geographical aggregations[12] that are relatively large areas about which there is an interest in recording, understanding, and managing changes over time. Geographical aggregations should take

11 In the SEEA EEA, EUs were termed Land Cover/Ecosystem Functional Units.
12 In the SEEA EEA, geographical aggregations were labeled Ecosystem Accounting Units.

into account administrative boundaries, environmental management areas, large-scale natural features (such as river basins), and other relevant factors (such as protected areas). Defining geographical aggregations for accounting purposes will also entail considering those aspects that will play a role in the way flows of ecosystem services are provided.

For forest ecosystem accounting purposes, delineation of EUs that may be considered forests is an important first step. Once these units are defined, they can be the focus of accounting in terms of understanding their condition, their extent (total area), and the flows of ecosystem services they provide. Importantly, the forest EU can be considered in relation to broader areas, such as river basins, administrative areas, or a country as a whole. Note that, as appropriate, forest EUs can be aggregated to obtain, for example, the total area of forests.

Physical accounts for ecosystem assets

Ecosystem condition and extent

Once the forest EUs are defined, we can proceed with their measurement for accounting purposes. The assessment of ecosystem assets encompasses measurement of two key concepts:

- Ecosystem extent, mainly related to the area and location of ecosystems
- Ecosystem condition, involving measurement of key characteristics by selecting indicators of each characteristic

The measurement of ecosystem extent is an extension of the approach to accounting for forestland. For the measurement of ecosystem condition, the approach followed in ecosystem accounting does not require users to measure every possible aspect of condition but rather to identify the most relevant characteristics of ecosystem assets to provide aggregated information on the condition of an ecosystem and changes in that condition. This approach involves:

- A description of ecosystem assets in terms of relevant characteristics
- An assessment of each characteristic in the context of the ecosystem as a whole and to identify relevant indicators for each characteristic

In the selection of relevant characteristics, it will be relevant to consider the set (or basket) of ecosystem services that are supplied by the ecosystem asset. In effect, the condition of the ecosystem should be assessed by taking into consideration its use.

Assessing changes in ecosystem assets: degradation, conversion, and enhancement

Three major changes can take place in terms of ecosystem assets: degradation, conversion, and enhancement. Degradation of a forest ecosystem covers only declines in ecosystem condition due to economic and other human activity and excludes changes due to natural influences (such as storms) and reductions in ecosystem service flow that are not due to changes in ecosystem conditions (reduced flow of timber due to a reduction in logging activities).

When the extent or composition of the ecosystem changes significantly or irreversibly, the change is referred to as ecosystem conversion. Different perspectives exist for measuring conversion, which are discussed in more detail in SEE EEA 4.32 to 4.35.

Ecosystem enhancement is the increase and/or improvement in an ecosystem due to economic and other human activity beyond those that may simply maintain an ecosystem asset.

Ecosystem extent and condition accounts

There are two primary physical accounts for the measurement of ecosystem assets: the ecosystem extent account and the ecosystem condition account. At the national level it is likely to be useful to compile an ecosystem extent account that covers all areas within a country and accounts for changes in the mix of different EU types. The structure of this type of account is shown in Table 12.

The types of EU shown in the Table are at a high level of land cover type, following the interim classification of land cover in the SEEA Central Framework. For tree-covered areas (class 6), additional detail on different types of forest may be added as appropriate. Note that the ecosystem extent account should build on the forestland physical asset account.

TABLE 12: Ecosystem extent account (thousand hectares)

	Type of Ecosystem unit														
	Artificial surfaces	Herbaceous crops	Woody crops	Multiple or layered crops	Grassland	Tree-covered areas	Mangroves	Shrub-covered areas	Regularly flooded areas	Sparse natural vegetated areas	Terrestrial barren land	Permanent snow and glaciers	Inland water blodies	Coastal water and Inter-tidal areas	TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Opening stock															
Additions to stock															
Managed expansion															
Natural expansion															
Upward reappraisals															
Reduction in stock															
Managed regression															
Natural regression															
Downward reappraisals															
Net change in stock															
Closing stock															

Ecosystem condition accounts may be structured as seen in Table 13. Here a selection of characteristics has been made, but this should be reviewed and considered specifically for forests in each country. Additional characteristics and indicators are likely to be appropriate.

At the national level, it is likely to be relevant to measure the condition of different forest EUs and hence compare the condition of forests in different locations. Alternatively, a structure that takes into account different types of forests, for example by altitude or species, may be of interest.

Accounts that assess ecosystem condition may benefit from using information from the resource-based accounts for individual environmental assets as these contain basic information for specific quantitative characteristics, such as timber resources.

TABLE 13: Measures of ecosystem condition and extent at end of accounting period

	Ecosystem extent	Characteristics of ecosystem condition				
		Vegetation	Biodiversity	Soil	Water	Carbon
Type of EU	Area	Indicators (e.g., biomass)	(e.g., species richness)	Indicators (e.g., organic matter content)	Indicators (e.g., water quality)	Indicators (e.g., net carbon balance)
Forest eco-system units:						
Broadleaved upland forest						
Conifer upland forest						
Conifer low land forest						
Mixed upland forest						

Flow accounts in the ecosystem-based approach

Ecosystem services are a central concept to connect characteristics of ecosystem assets with the benefits received from ecosystems by people through economic and other human activities. The flow accounts in this approach encompass the measurement of ecosystem services that reflect flows of materials and energy, services related to the regulation of an ecosystem, and flows related to cultural services (SEEA EEA 3.2).

To measure the flows of these ecosystem services, three broad categories of services are considered:

- *Provisioning services* reflect material and energy contributions generated by or in an ecosystem—for example, timber, game, berries, or fodder.

- *Regulating services* result from the capacity of ecosystems to regulate climate, hydrological and bio-chemical cycles, earth surface processes, and a variety of biological processes; these services often have an important spatial aspect—for instance, the flood control service of an upper watershed forest is only relevant in the flood zone downstream of the forest.
- *Cultural services* are generated from the physical settings, locations, or situations that lead to intellectual and symbolic benefits that people obtain from ecosystems through recreation, knowledge development, relaxation, and spiritual reflection.

The Common International Classification of Ecosystem Services (CICES) provides additional detail within these broad groups (see SEEA EEA Table 3.1).

Commonly, ecosystem services are conceptualized in terms of the types of benefits they contribute. The ecosystem-based approach enables users to identify a spectrum of benefits, ranging from market benefits and quasi-market benefits to non-market benefits. Ecosystem services contribute to the generation of all three types of benefits.

Physical accounts for ecosystem services

The physical accounts of ecosystem services organize the information on the supply and use of ecosystem services by type of service, by ecosystem asset, and by economic units involved in generating and using the various services (SEEA EEA 3.51):

- *Provisioning services* will generally be measured in units that will reflect the relevant physical properties of the underlying input, such as tons or cubic meters of timber. All measures should reflect the total flows of the ecosystem service over an accounting period, usually one year.
- *Regulating services* will also be measured in a variety of units. For example, the service of carbon sequestration would normally be measured in terms of tons of carbon sequestered.
- *Cultural services* are likely to be measured in units related to the people interacting with the ecosystem and using its services (such as the number of people visiting a site or the time spent using the service).

Chapter 5 shows examples of suitable indicators for the measurement of the ecosystem services provided by forest ecosystems. Table 14 shows some examples of measurement approaches for the different types of services, based on examples provided in the SEEA EEA. Although the initial approach to assess the overall ecosystem should recognize the bundle of services supplied, a decomposition will need to be adopted to measure these services. A useful starting point for the measurement of individual ecosystem services is likely to be at the level of the EU.

TABLE 14: Physical flow of the supply of ecosystem services for different forest ecosystem unit

	Type of forest			
	Broadleaved upland forest	Conifer upland forest	Conifer low land forest	Mixed upland forest
Type of ecosystem services (by CICES)				
Provisioning services	e.g., tons of timber			
Regulating services	e.g., tons of CO_2 sequestered			
Cultural services	e.g., number of visitors/hikers			

Following the supply use identity that operates in the flow accounts, the total generation of a single ecosystem service should equal the total use of that service. Because the ecosystem approach is area-based, however, it is likely that the use (consumption) of services generated within a single EU may not take place within the same EU. Therefore, similar to the supply and use tables in the resource-based approach, the supply and use of ecosystem services can be attributed to the different types of ecosystem units. Table 15 illustrates how these transactions can be reflected.

TABLE 15: Supply and use of ecosystem services for a geographical aggregation

	Supply of ecosystem services					Use of ecosystem services				
	Enter-prises	House-holds	Gov't	Rest of the world	Total	Enter-prises	House-holds	Gov't	Rest of the world	Total
Type of ecosystem services (by CICES)										
Provisioning services										
Regulating services										
Cultural services										

Monetary flows

The estimation of the value of ecosystem services and ecosystem assets in monetary terms is complex. In a purely accounting context, the complexity exists because ecosystem services and ecosystem assets are generally not traded in markets in the same way as other goods, services, and assets. Valuation therefore involves the estimation of "missing prices" or the identification of prices that are implicitly embedded in the values of marketed goods and services. These aspects are further developed in the Chapter 6.

One way to bring this information together is to create presentations that combine measures in physical terms for ecosystem services and ecosystem assets with standard economic measures such as value added, income, and employment.

A second way of considering ecosystem accounting in monetary terms is to bring together valuations of stocks and flows of ecosystem assets into an ecosystem asset account, following the standard asset account structure outlined in the SEEA Central Framework.

A third approach is to use valuations of ecosystem services and assets in monetary terms to augment the standard national accounts and aggregates. The motivations underpinning this approach are that it may be beneficial to provide information on economic and other human activities that take place outside the market and/or are not recorded in the standard economic measures of production, consumption, income, and wealth. Chapter 6 provides a description of approaches for the valuation of ecosystem services and assets.

Monetary ecosystem asset accounts follow the structure of the monetary asset accounts described in the resource-based framework. However, this framework has to be broadened, as in the resource-based approach only the provisioning services of timber resources are accounted for. Therefore, the application of such a framework in an ecosystem asset framework requires that the values of all ecosystem service flows are interpreted as analogous to income flows.

The basic structure of an ecosystem asset account is shown in Table 16. Since the estimates are compiled in monetary terms, estimates for different ecosystem assets can in theory be summed to provide higher-level aggregates. Given the potential for aggregation, it may be more practical to consider the development of asset accounts for particular EUs and then form geographical aggregations.

TABLE 16: Monetary ecosystem asset account

	Ecosystem Unit Type			Total
	Forests	Agricultural land	Other	
Opening stock of ecosystem assets				
Additions to stock				
Regeneration – natural				
Regeneration – through human activity				
Reclassifications				
Total additions to stock				
Reductions in stock				
Reductions due to extraction and harvest				
Reductions due to ongoing human activity				
Catastrophic losses due to human activity				
Reductions due to natural events				
Reclassifications				
Revaluations				
Closing stock of ecosystem assets				

4.5 Environmental activity accounts and related flows

The scope of environmental activities covers economic activities whose primary purpose is to reduce or eliminate pressures on the environment or to use natural resources efficiently. The various activities are grouped into two broad types of environmental activity listed according to the Classification of Environmental Activities (CEA) (SEEA CF 4.2.2).

The primary purpose of environmental protection activities is the prevention, reduction, and elimination of pollution and other forms of degradation of the environment; the protection of biodiversity and landscapes, including their ecological functions; monitoring of the quality of the natural environment (air, water, soil, groundwater); research and development on environmental protection; and the general administration, training, and teaching activities oriented toward environmental protection.

The primary purpose of resource management activities is preserving and maintaining the stock of natural resources and hence safeguarding against depletion; restoring natural resource stocks (increases or recharges of natural resource stocks); the general management of natural resources (including monitoring, control, surveillance, and data collection); and the production of goods and services used to manage or conserve natural resources.

Beyond these environmental activities, two broad economic activities related to the environment can also be analyzed. These activities are not considered environmental in the SEEA, due to the specific and direct effect of their production processes on the environment. However, they may be of particular interest in the assessment of environmental impacts and the development of environmental policy. The two economic activities are:

- Natural resource use activities that involve the extraction, harvesting, and abstraction of natural resources and activities
- Activities associated with the minimization of the impact of natural hazards on the economy and society—provisioning for fighting the effects of forest fires would be recorded in this section, for example

There is no specific correspondence between the classes of environmental activity just described and the classification of economic activities reflected in the International Standard Industrial Classification, since—at least in concept—it is possible for all economic units to undertake environmental activities commonly as a secondary or ancillary activity. For the purpose of focusing measurement around forestry, however, it is likely that most relevant activity will be undertaken by units classified to ISIC classes Forestry (021), Logging (022), or Support Services to forestry (024).

Two different sets of information can be compiled to provide information on environmental activities: Environmental Protection Expenditure Accounts (EPEAs) and statistics on the Environmental Goods and Services Sector (EGSS).

The EPEA follows the accounting principles of the SNA. It has a set of four tables that show, from a demand perspective, the various expenditures undertaken by economic units for environmental protection purposes. It can be used to analyze the extent of environmental protection activities and to assess how expenditure on environmental protection is financed.

The EGSS considers environmental activities from a supply perspective, and EGSS statistics present information on the production of environmental goods and services in as much detail as possible. It encompasses all products that are produced, designed, and manufactured for purposes of environmental protection and resource management. The EGSS statistics show each type of output of environmental goods and services, classified according to the CEA classification and linked to its specific producer.

Although it has not been sufficiently developed, in principle it is possible to elaborate a resource management expenditure account for specific resources, such as timber. Resource management expenditure accounts, as for the EPEA, would consist of accounts showing the production and the supply and use of resource management–specific services, as well as national expenditure on resource management.

Finally, the flow of environmental taxes and subsidies may be of particular interest to analyze the role of government in the interactions between the economy and forests. Although these transactions are already recorded in the national accounts framework, they are not generally separately identified as relating to the environment.

More information on these accounts and statistics may be found in Chapter 4 of SEEA Central Framework.

4.6 Challenges

Challenges related to the informational status

To adopt ecosystem-based accounting, countries will need to establish the relationship between ecosystem condition and extent and the capacity to supply ecosystem services for the ecosystems in their countries. At present there is incomplete knowledge of the relationships between ecosystem extent and condition and the future flows of ecosystem services, although it is an active area of ecological research (SEEA EEA 2.34). Further there is the challenge of applying consistent valuation techniques and the need to manage the involvement of multidisciplinary expertise.

Consequently, compiling basic resource accounts may provide a useful starting point. A number of basic resource accounts that are fundamental to ecosystem accounting will typically need to be developed. These include land accounts, carbon accounts, and resource-based forest accounts.

A useful step for policy purposes would also be to clearly define the scope of resource management activities in order to establish a resource management account for forests. This may be particularly the case where there are significant quantities of timber resources outside of forest areas.

In the long term, the objective should be to develop a standard base of information on forestland, the status of forest ecosystems, and flows of forest resources. As well, since the resource-based approach does not value, in monetary units, those ecosystem services outside of the standard national accounts boundary of production and income (that is, primarily timber resources from forests), a longer-term objective should be valuing other forest ecosystem services in monetary units, which would allow governments to highlight the importance of these flows and the broader importance of forests beyond the harvesting of timber.

On the research agenda, it must be recognized that defining the depletion of forest-related resources is not straightforward and that the conceptualization and measurement of this accounting term needs further research and application.

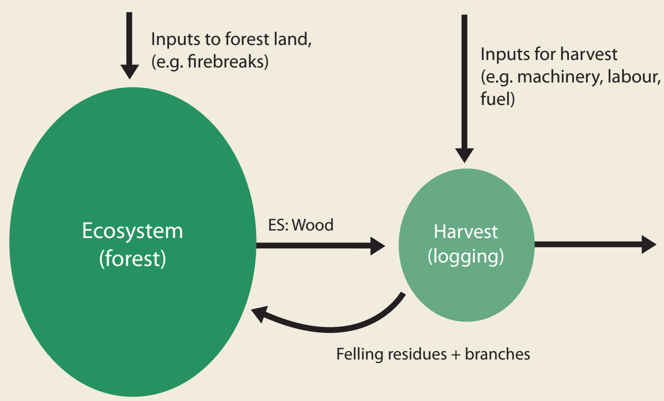
Challenges related to the institutional efforts

Placing forest accounting, especially forest ecosystem accounting, firmly within the scope of national accounting requires many disciplines to consider measurement in new ways. For ecologists, it requires creating clear distinctions between ecosystem assets and service flows within an ecosystem and to differentiate between those aspects of ecosystems that provide direct benefits to economic and other human activities and those aspects of ecosystems that in effect support the provision of these benefits. For national accountants, it requires considering the expansion of the production boundary required for ecosystem accounting and alternative approaches to valuation.

These developments are likely to occur only in the medium to longer term as testing and piloting of ecosystem accounting develops and as further refinements are made to concepts and methods (see Boxes 14, 15, and 16). In the shorter term, a focus on resource-based accounts is an important initial step. In all accounting work, however, discussion of these topics among ecologists, national accountants, and other actors will be essential to making progress in this area.

BOX 14: Measurement approaches for provisioning services

The Figure shows a forest ecosystem from which wood and non-timber forest products are obtained. For logging or for extraction of other forest products, such as cork or berries, a number of inputs are required (such as labor, machinery, and fuel). The product (benefit) resulting from the logging activity is logged wood, with felling residues returned to the ecosystem.

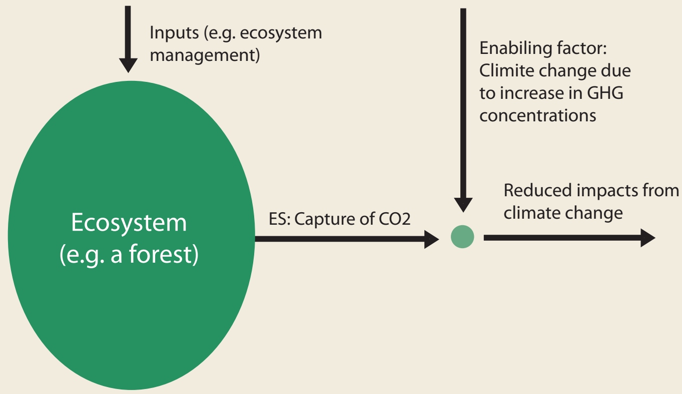


In this case, both the benefit (logged wood or extracted cork, for example) and the ecosystem services (timber and cork) can be measured in terms of kg/hectare/year. The difference between the two is that the ecosystem service represents wood or cork at the moment immediately before it is felled/extracted, whereas the benefit arises immediately after felling/extraction.

BOX 15: Measurement approaches for regulating services

Often the services of carbon sequestration and carbon storage are labeled by the single term “carbon sequestration.” However, they are quite different ecosystem services, albeit linked within the broader carbon cycle.

The service of the sequestering of carbon is equal to the net accumulation of carbon in an ecosystem due to growth of the vegetation and accumulation in belowground carbon reservoirs.

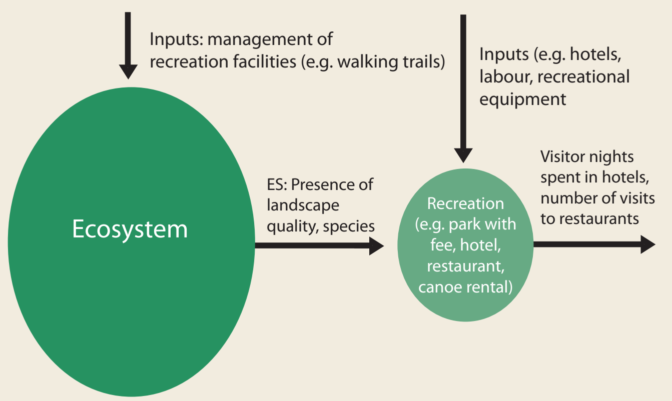


The ecosystem service of carbon storage is the avoided flow of carbon resulting from maintaining the stock of aboveground and belowground carbon sequestered in the ecosystem. Therefore, the avoided emissions may be calculated. Under this approach, the avoided emissions only relate to the part of the stored carbon that is at clear risk of being released in the short term due to land use changes, natural processes (such as fire), or other factors.

The Figure shows the conceptual model of the ecosystem service as a function of ecosystem state and enabling factors. “Enabling factors” is the term used to describe the context without which the ecosystem service would not be delivered. In this case, carbon sequestration and carbon storage provide benefits to society due to the negative impacts resulting from the increase in greenhouse gas emissions, which in effect places a value on these ecological processes. Ecosystem management will generally affect the net sequestration and/or the storage of carbon in the soil.

BOX 16: Measurement approaches for cultural services

Forest ecosystems provide an opportunity for tourism and recreation. The service usually involves some degree of investment in the ecosystem. In physical terms, this ecosystem service can be measured in terms of the number of people visiting the ecosystem.
The benefits accrue to visitors themselves and to nearby suppliers of tourism and recreational facilities to the extent that they can attribute their operation to the ecosystem.



Physical measurement of the ecosystem involves recording the number of visitors, in terms of visitor-days, or overnight stays, to ecosystems (see Figure). As in the case of provisioning services, the use of ecosystem services in tourism requires that a specific activity be undertaken (that is, the recreation activities by people in an ecosystem).

5. Compiling physical accounts for forests

The structure of the physical accounts for forests is described in Chapter 4. This chapter highlights the methodological aspects and alternative data sources that might be useful when compiling forest accounts in physical terms.

The context in which different countries or regions decide to compile forest accounts can vary significantly. The variances can be the result of data availability, frequency of data acquisition, and access to pertinent datasets. As a result, this chapter focuses on general indicators of forest stocks and flows and proposes a number of potential data sources to track these indicators. The final compilation will depend very much on the priorities of each country or region, data availability, and the choice of meaningful indicators with ecological, societal, and policy relevance.

The data sources described in this chapter refer to the various types of data that may be generally accessible, usually in the form of primary data or data collated and aggregated for statistical purposes, such as surveys of timber production and income. In addition, there are commonly individual studies or assessments of forestry and timber production or of forest ecosystem services as well as similar studies that may use information from these sources but that will commonly incorporate additional information from detailed one-off investigations or more-detailed analysis within analytical frameworks and models.

It is beyond the scope of this *Sourcebook* to provide a listing of the various studies that may be found. Compilers of accounts should search for relevant studies that have been undertaken in their country. By way of additional guidance in this area, a technical note to complement the *Sourcebook* is planned that will describe some of the more comment analytical frameworks used to model supply and demand for forest products. These include WISDOM (Woodfuel Integrated Supply/Demand Overview Mapping), Mofuss (Modeling fuelwood savings scenarios), and fNRB (fraction of non-renewable biomass). There should be clear overlaps between the data sources used to run these types of models and the data required to compile forest and timber accounts.

5.1 Data sources

This section presents an overview of data sources for forests and forest resources that are relevant for compiling forest accounts. Each data source has various areas of focus, and hence a complete coverage of information is not possible from one source. A key aim of the accounting frameworks presented in this *Sourcebook* is to describe how to integrate these various data sources.

The relevance of each data source will vary depending on the specific situation of a country or region. It is beyond the scope of the chapter to have a complete set of indicators, and the final set of chosen indicators and data sources will depend on the local conditions of important ecosystem services, data availability, and linkages between forests and the economy as a whole. For this chapter, seven categories of data sources are explained:

- Forest inventories and forest statistics (including FAO *Global Forest Resources Assessment* and other FAOSTAT statistics)
- Spaceborne remote sensing
- Airborne remote sensing
- Spatial datasets for land cover and land use
- Forestry production and income statistics from national accounts
- Non-forest statistics
- Other spatio-temporal datasets

Forest inventories and forest statistics

The primary source of quantitative information for forest areas (stands) are forest inventories as well as the dedicated collection of forestry statistics. Forest inventories are based on statistical sampling over forest stands grouped in homogeneous strata. They are implemented at different levels of detail and can be designed to assess forest resources at different scales: forest unit, municipal, regional, national, or supranational level.

In addition to forest inventories, data collected on a continuous basis by national forest authorities can also aid in the compilation of forest accounts. The mandate of forest authorities normally includes keeping track of management activities (such as thinning or harvesting) as well as data on afforestation, reforestation, and land use change. Other institutions—including research institutions, forester associations, environmental organizations, and commercial forest companies—may maintain valuable datasets and could be questioned regarding specific forest-related topics in case inventories or official forest statistics are not complete or up-to-date.

The Food and Agriculture Organization is an important source of forest data, summarizing available national-level data. Forest data from the entire world at a country level are gathered by the FAO Forestry Department. These datasets are made public through the FAOSTAT portal. The FAOSTAT database contains a series of variables related to forestry production and trade flows.

Additionally, as noted in earlier chapters, FAO publishes a Global Forest Resources Assessment every five years (www.fao.org/forestry/fra/en/). The data in the FRA originate from country reports and remote sensing and include information on forestland, timber, employment, and other forest-related topics.

Despite the suitability of forest inventories data for constructing asset accounts, some drawbacks can be identified. The frequency with which forest inventories are conducted and the area inventoried may not match the envisioned accounting period or the geographical coverage. When the focus is on timber or other tree resources, conventional forest inventories may fail to include the stock of trees outside the forest.

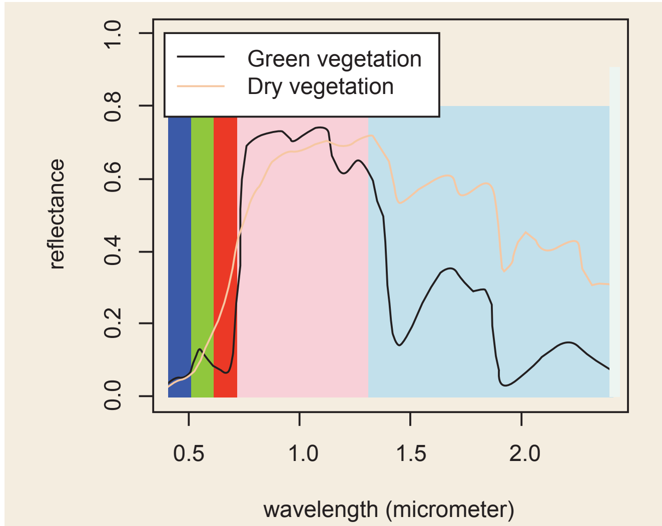
Also, the nationwide nature of the information included in FRA may not be detailed enough to support specific policy applications, which is an important goal of forest accounting. In this respect, data from inventories might be combined with routinely gathered forest statistics by the national forest service and forester associations. New data are constantly added to those datasets and can be useful in tracking changes in stock. Moreover, the national accounts and commercial statistics can be queried to derive the volume of harvested and traded timber.

Spaceborne remote sensing

Developments in spaceborne remote sensing (RS) have been greatly motivated by the need to monitor natural resources. Early missions like the Landsat-1 and the AVHRR sensor onboard U.S. National Oceanic and Atmospheric Administration satellites were pioneers in the use of Earth observation for environmental applications.

Spaceborne RS is possible because of the reflective properties of vegetation. Spaceborne RS measures energy interacting with objects on Earth's surface. Sensors on satellite platforms are able to capture energy reflected by objects on Earth in certain electromagnetic regions. Due to growing interest in monitoring vegetation from space, several satellite platforms have sensors that are able to capture the distinctive reflective properties of vegetation. That is important for forest accounting, as the main concern will be the quantification of vegetative systems. Figure 5 illustrates the typical reflectance pattern of vegetation over a segment of the electromagnetic spectrum encompassing the visible (represented with blue, green, and red background), near-infrared (pink background), and short-wave infrared (light-blue) regions. The Figure shows the reflectance pattern of green healthy vegetation and dry vegetation.

FIGURE 5: Typical reflectance pattern of vegetation



Developments in spaceborne RS are ongoing and have seen a surge in applications because of increases in computational power and the need to address environmental challenges at a global level. Spaceborne RS can be an important data source for forest accounting because it is likely to be an efficient data collection mechanism, especially for countries with large forested areas such as Canada, the United States, Brazil, and Russia. Three particular features of spaceborne RS stand out: georeferencing, spatial and temporal resolution, and affordability.

First, forests can be thought of as spatial entities. Many of the environmental services provided by forests are related to their position in respect to other landscape elements (urban areas, floodplains, agriculture areas, steep slopes, etc). Data from RS are related to specific locations on Earth according to a particular geographical projection. Remote sensing imagery can therefore be combined with other spatial datasets when quantifying forest resources within the administrative or water catchment boundaries, localizing the provision of ecosystem services, or implementing modeling schemes.

Second, one of the most appealing factors of remote sensing is the pace at which images are generated and the increasing spatial resolution of the products. The Terra and Aqua satellites (carrying the MODIS sensor) visit every point on Earth every day or every second day, and Landsat covers Earth in 16 days. Terra and Aqua satellites deliver products with 250, 500, and 1000m, while Landsat produces pixels of 30m. Considering the spatial and temporal resolution, the selection of RS products often presents a trade-off in that high spatial resolution accompanies low temporal resolution and vice versa.

Third, in addition to the suitability of the technical aspects of RS for studying vegetation, it is also relatively inexpensive to obtain RS data. High-resolution data or on-demand delivered data offer valuable information that serves specific purposes but may not be affordable for projects with budget constraints. Fortunately, an increasing number of RS datasets are offered free of charge by public institutions. Some of the most common RS data sources for vegetation studies are listed in Table 17. Software options for managing geographic information has been growing as well. In particular, free and open source options are becoming more available.

TABLE 17: Commonly used spaceborne RS data sources for vegetation studies

Platform/sensor	Features	More information
Early Landsat missions		http://landsat.usgs.gov
Landsat ETM+	Resolution:120 m for thermal infrared band and 30 m for multispectral bands. Each scene covers an area of 185 x 185 km. Temporal resolution is 16 days.	http://landsat.usgs.gov
Landsat 8	Launched in 2013	http://landsat.usgs.gov
SPOT-Vegetation	Resolution: 1 km. Launched in 1998; specially meant for monitoring vegetation globally	http:/vito-eodata.be http://www.gmes-geoland.info/
PROBA-V	Resolution: 300 m. Launched in 2013. Follow-up mission of SPOT-Vgt	http:/vito-eodata.be
MODIS	Resolution: 250-500-1000 m. Multispectral sensor onboard Terra (from 2000 to present) and Aqua (from 2002 to present)	https:/lpdaac.usgs.gov
AVHRR	1-km ground sampling distance with multispectral data. Onboard the NOAA satellite series. (1980 to present)	http://edc2.usgs.gov/1KM/avhrr_sensor.php
IKONOS	Commercial satellite delivering high resolution imagery: 1m (panchromatic) and 4 m (multispectral bands)	http://www.digitalglobe.com
QuickBird	High resolution imagery (2.4 – 0.6 m) and panchromatic and multispectral imagery from a constellation of aircraft	http://www.digitalglobe.com
ASTER	Spatial resolution: 15-90 with 14 spectral bands. Onboard the Terra satellite. Data from 2000 to present	http://asterweb.jpl.nasa.gov/data.asp
Hyperion	Spatial resolution: 30m. Hyperspectral images with 220 bands ranging from visible to short wave infrared	http://eo1.usgs.gov/sensors/hyperion
Sentinel-2	Not yet launched. European Spatial Agency. 10, 20, 40 m. Temporal resolution: 5 days	https://earth.esa.int/web/guest/missions/esa-future-missions/sentinel-2

Forest accounts do not record sub-annual changes, and in this sense there is a preference for greater accuracy in data collection. It is possible to select RS products offering high spatial resolution. Landsat imagery represents an interesting option. The large area coverage (about 185 x 185km), the spectral information, and the spatial resolution of Landsat images have been regarded as most suitable for operational use when combined with forest inventory plots. However, a moderate to high temporal resolution may be required for certain measurements in forest accounting. In particular, estimations the rely on analysis of time series will require higher temporal resolution.

Airborne remote sensing

Airborne remote sensing has a long history in forest measurement. Aerial photographs and photogrammetric techniques are part of the conventional toolkit of forest surveyors. Optimal use of aerial photos takes place when the flight campaign has been designed such that there is overlap between two consecutive aerial photos and between adjacent flight lines. This feature makes interpretation of photos with stereoscopic views (3D) possible. Stereoscopy eases the stratification of forest by function of species, ages, density, or other useful criteria as well as the classification of forest stands by function or location with respect to topographic features (valleys, hill tops, slopes, aspect, etc). The scale may allow the derivation of mathematical relations between tree crown and standing timber volume, the estimation of tree heights, and other variables of interest.

The spectral resolution of traditional aerial photos covers the visible region and sometimes the infrared region. These photos can be produced in gray tones, real color, or false color. The possibilities have expanded significantly in recent years as new sensors have been developed, and the incorporation of those innovations in forest measurement is evolving at a fast rate.

Other developments relating to forest measurement include airborne hyperspectral remote sensing, Light Detection and Ranging (LiDAR), and unmanned airborne vehicles. LiDAR systems measure the distance between objects on Earth's surface and the sensor. The distance measurement is based on recording the time interval between the emission of a laser pulse and its reflected return signal. The application of this technology in forest measurement has evolved substantially from the early studies in the 1990s. Data from LiDAR systems can be used to segment the forest into height and age classes, ecologic succession phases, density, crown characteristics, etc.

Spatial datasets for land cover and land use

Spatial datasets for land cover and land use provide information on the location and extent of land cover types and land uses at the country or regional level. Commonly, the information is presented in the form of maps. A number of aspects can be highlighted with regard to the relevance of land cover maps for forest accounting.

First, a land cover map is a basic source of information from which the location and dimensions of forested land can be obtained. This meets the requirement of accounting for the surface covered by wooded land and forest, which is an important aspect of physical accounts.

Second, in contrast to national estimates, land cover maps allow the derivation of the spatial distribution of ecosystem services related to specific forest ecosystems. This is a fundamental input toward the quantification and understanding of linkages between forest resources and the economy.

Third, the classification system used to partition the surface into land use and land cover regimes indicates the classes that are relevant in the local context. Although global classification systems have been defined (FAO, CORINE, Globcover, etc.), forest accounting may favor the use of locally defined classification systems, as they may reflect the forest categorization that is most relevant for ecological, management, and policy considerations at the local level. Where local classification systems are used, however, it is highly recommended to embed or harmonize these classifications with international systems to support cross-country comparisons and global reporting.

While the potential to develop spatial datasets and maps is significant and likely of great value in forest accounting, it is important to understand that these data are a two-dimensional representation of a three-dimensional real world. The translation of data from three to two dimensions requires a range of assumptions and the application of modeling techniques. Further testing is needed to consider which assumptions and models are most appropriate for forest accounting, particularly in relation to comparisons across different areas and ecosystem types and over time.

Forestry production and income statistics from national accounts

Various forest products are part of the intermediate or final consumption of many economic activities, and many products are part of the final consumption by households. These flows are conceptually within the scope of national accounts; hence a country's national accounts can constitute an important data source for information on flows of forest goods to different economic sectors.

However, it may commonly be the case that data in the national accounts are not compiled at a sufficient level of detail to support extended analysis of the forest sector. Further, focus in the published national accounts will be on data in monetary terms only. This being the case, it will be necessary to supplement data in national accounts with more detailed information from other sources. It will be relevant to use the aggregate national accounts data to ensure that the detailed forestry data are framed consistently within a whole economy setting. In addition, it will be relevant to work with national accounts compilers to determine whether more detailed forestry statistics can be incorporated in compilation processes to improve the quality and coherence of all forest data.

Generally, national accounts data are not compiled at a spatial level, although in modeling exercises these may serve as a basis for a regional analysis of flows of forest goods and services by providing industry-level detail that can be attributed to regional levels. Within the national accounts framework, if data on the spatial distribution and size of companies are available, the demand of companies for forest goods can be traced to the different forest ecosystems across the country or region under consideration, although this will require information beyond the standard national accounts.

Non-forest statistics

A large and varied set of data sources can support the elaboration of forest physical accounts.

- *Livelihood and household surveys:* Rural populations demand goods and services that are related to both forests and trees outside forests. For the latter, the demand for timber, firewood, hunting resources, and other supplies is typically not considered in forest inventories or forest surveys. This kind of connection between humans and ecosystems is more likely registered in surveys addressing livelihood-related issues (see Box 17).
- *Economic statistics:* Although many forest products are part of national accounts, detailed information on forest products regarding pricing, origin, trade, losses, etc. may be registered in different levels of detail by other potential data providers, such as entrepreneurs organizations, trade unions, etc.
- *Air pollution, water budget, and water quality statistics:* Air pollutants may damage forest foliage. In accounting for forest health, records on exposure of forest areas to air pollutants are important. Data on stream and river discharge and indicators of water quality can also be relevant for forest accounting, as the regulation of water cycle is an important environmental service related to forest cover.
- *Tourism and recreation statistics:* It is common for forests to be places for tourism and recreation. Information on visitation rates to forests, particularly to national parks, are commonly compiled, and often studies are undertaken assessing the economic contribution of tourism to areas with forests. Separately, studies may also be completed on the human health benefits from forests in terms of both physical health (clean air, water, etc.) and mental well-being. Spiritual and cultural connections to forests may also be areas of interest for measurement.
- *Agriculture and livestock statistics:* Various forest ecosystem services are

related to agriculture production. For instance, improving livelihoods by implementing agroforestry schemes or grazing in silvo-pastoral systems are important in many countries. Data on these services are likely to be found in agriculture or livestock statistics.

BOX 17: Living Standards Measurement Survey in Vietnam

As part of an ongoing program of household living standards surveys, Vietnam collected additional information in 2004 and 2008 concerning agricultural and forestry activity of households. The household survey modules included information on output from forestry activities, expenditure on forestry activities, and land related to forestry.

The collection covered a range of forestry outputs from 10 main types of tree, including mu oil tree, cinnamon tree, anise tree, pine tree, varnish tree, trees for wood, bamboo, fan palm tree, and water coconut palm. This range of trees highlights the relevance of non-wood forest products to households in Vietnam.

Since the information was collected in tandem with many standard household survey items such as household size and composition as well as housing and consumption expenditures, it was possible to undertake analysis of the importance of forestry at the household level.

Other spatio-temporal datasets

The nature and magnitude of the ecosystem services provided by forests is greatly determined by their geographical location with respect to other landscape elements and topographical features and to the spatio-temporal context in which they exist. Both of these factors will have considerable impact on the assessment of the relative importance and associated valuations of forests.

The existence of geo-referenced datasets on human settlements, topographic features, soil types, and other relevant variables are basic requirements for understanding and describing the condition of forests and assessing the flow of ecosystem services to the economy. Since several variables defining the flow of ecosystem services can be highly variable over time, the dynamic character of several determinants of ecosystem services should be accounted for.

In ecosystem management and the definition of rights over forest goods and services, natural boundaries are often subject to administrative borders that determine the roles of authorities and users in governing and managing the natural resources. Therefore, spatial datasets on the different levels of administrative organization of the country (municipalities, districts, counties, etc.) are important as well.

5.2 Compilation of asset accounts

Forest assets can be expressed as land covered by forest ecosystems (ecosystem-based accounts) or as the stock of one or more forest products of interest (resource-based accounts). In the first case, the stock and its changes over an accounting period are recorded in surface units (hectares, square kilometers, etc). In the resource-based accounts the stocks are recorded in relevant units (typically a volumetric unit, m3) depending on the resource. Table 18 presents the basic components of the asset accounts and a non-exhaustive list of indicators and potential data sources.

TABLE 18: Typical indicators and data sources for constructing the forest asset accounts

A. Assets accounts based on forestland		
	Indicator(s)/unit	Data source
Opening stock of forest and other wooded land		
Additions to stock		
Afforestation	Afforested area (ha) Density (trees/ha)	1, 2, 3
Natural expansion	Area (ha)	1, 2, 3
Reforestation	Reforested area (ha) Density (trees/ha)	
Reductions in stock		
Deforestation	Deforested area (ha)	1, 2, 3
Natural regression	Area (ha)	1, 2, 3
Closing stock of forest and other wooded land		
B. Assets accounts based on standing timber		
	Indicator(s)/unit	Data source
Additions to stock		
Growth	Natural growth of timber volume (m^3)	1
Timber in young trees (not considered in previous accounting period)	Volume in trees recently classified as timber (m^3)	1
Reductions to stock		
Tree harvest	Harvested timber during the period (m^3)	1, 4
Tree losses	Losses in timber volume due to fires, disease, catastrophic events, etc (m^3)	1
Closing stock of standing timber		

Data Sources:
1. Forest inventories and forest statistics (including FRA and other FAOSTAT statistics)
2. Spaceborne remote sensing
3. Airborne remote sensing
4. National accounts production data

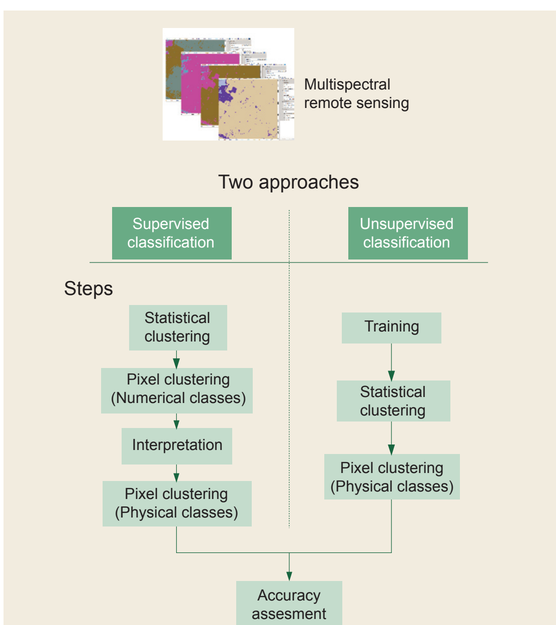
Approaches to land cover mapping

Land cover, land use, and forest maps are essential data sources in an ecosystem-based approach. Land cover maps constructed at national or subnational level are preferable data sources as they contain highly detailed information and are based on locally relevant land cover classification systems. Alternatively, if no up-to-date data are available, an approximation of the location and extent of forestland might be available in global land cover maps like the European Space Agency's Globcover, the MODIS land cover product, Ecoclimap, and similar sources.

In certain circumstances, alternatives to the available land cover maps may be required, as the maps may be outdated, more detailed land cover data may be required, or the classes in the land cover map may not reflect a meaningful segmentation of the study area for the ecosystem services of interest. In that case, a land cover/land use map can be built using multispectral imagery.

The elaboration of land cover maps from multispectral imagery is based on the fact that the land cover classes exhibit characteristic spectral patterns. In other words, land cover classes can be defined as a function of the reflectance values in different regions of the electromagnetic spectrum. Therefore, the construction of land cover maps is based on the statistical clustering of pixels of similar reflectance values in different regions of the electromagnetic spectrum. Two main methodological approaches can be followed for constructing a land cover map from multispectral imagery: supervised and unsupervised classification. These approaches are illustrated in the scheme of Figure 6.

FIGURE 6: Methodological approaches to land cover mapping

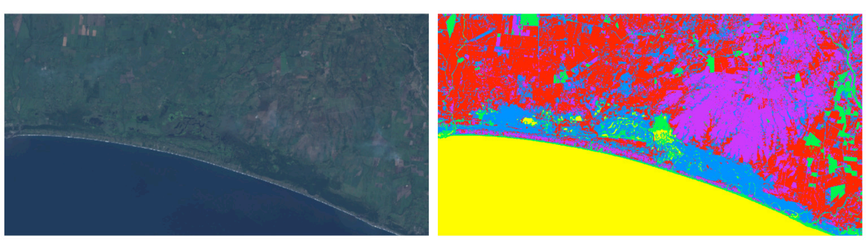


The supervised classification approach starts with existing knowledge about the correct classification based on a number of sites in the area of interest. This information is registered such that the reflectance values of the known locations are associated with the land cover classes of those locations. This phase is referred to as the training phase. The information collected in the training phase is used in the clustering algorithm to steer the clustering process so that all pixels in the area of interest are assigned to one land use class. In the next step, the spectra of all pixels are analyzed and each pixel is associated to a class based on its similarity to the spectral signatures obtained during the training phase.

The unsupervised classification approach does not start from previous knowledge of locations and the class they belong to. A cluster analysis is performed so that the area of interest is partitioned into a user-defined number of classes. A numerical value is assigned to each class. The resulting partition should then be interpreted to give a physical meaning to the obtained classification.

Figure 7 provides an example of this classification approach. The region of study is the Pacific coast in southeastern Guatemala. The most notable permanent vegetation type in this region is the mangrove forest. This forest ecosystem fulfills various ecological and economic functions in the region. Yet it is threatened by factors like expansion of marine salt exploitation facilities, wood harvest, reduced discharge of rivers, urbanization, etc. The left-hand side of the Figure shows the area as seen by Landsat 8 in real color, and the right-hand side presents the results of unsupervised classification into an arbitrarily defined five classes. In this exercise, the forested areas were grouped in one class, depicted in light blue on the right. Within this class, the mangrove area stands out as the forested area along the coast. Water is represented in yellow, and the cropped area in red, purple, and green as the class presenting different degrees of bare soil influence and humidity.

FIGURE 7: Unsupervised classification with an arbitrarily defined five classes in a coastal region in southeastern Guatemala

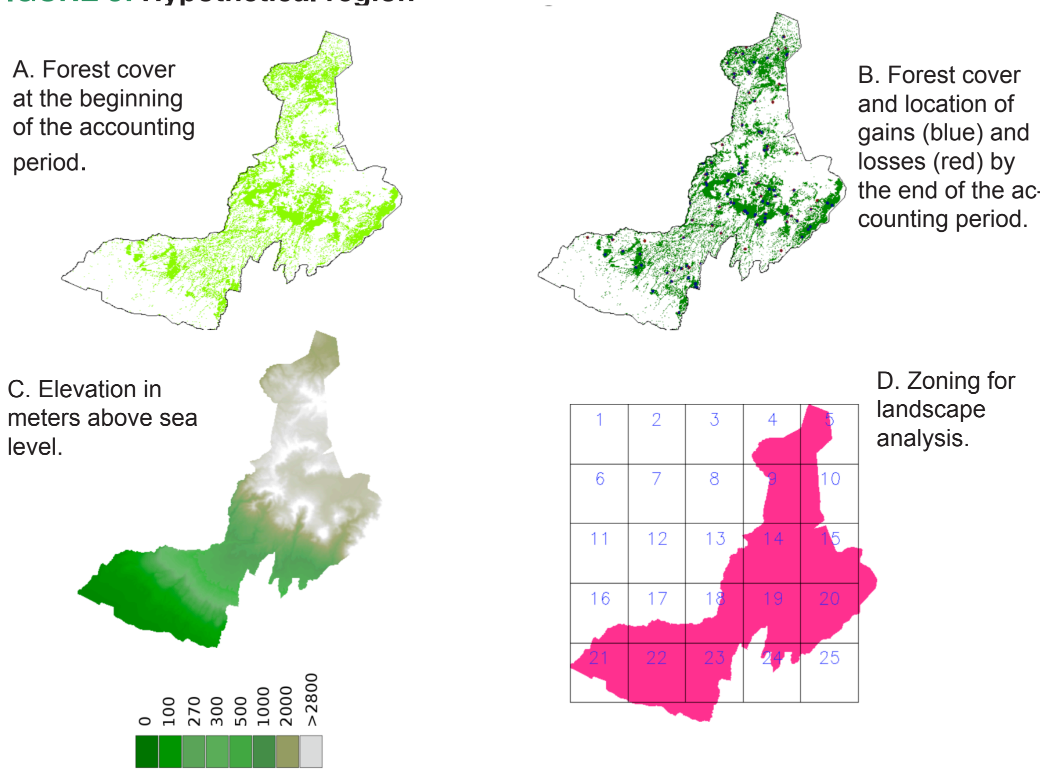


A B

Conducting this kind of analysis at different timestamps allows the assessment of gains and losses in the extent of forestland and the overall evolution of the spatial arrangement of landscape elements. In this respect, it is pertinent to mention that various methodologies have been developed to detect change in land cover. Coppin et al. review different methods of digital change detection for ecosystem monitoring.

For illustrative purposes, Figure 8 shows a hypothetical area where forest cover has been monitored. The status of forest cover is presented for two timestamps, A and B, which are taken as the beginning and the end of the accounting period. The change recorded by the end of the accounting period is indicated in Figure 8B (losses in red, gains in blue). Additionally, maps on the elevation and a grid-like zoning of the area are presented.

FIGURE 8: Hypothetical region



Forestland asset accounts

Table 19 presents the general forest asset account for the region and accounting period under study. The data in Table 19 are an example of the simplest presentation of forest asset extent accounts. For the purposes of policy evaluation and planning, a more detailed table that partitions the data according to the drivers of change may be necessary. For instance, additions may be due to new forest plantations, natural succession, change in land use regulations, etc. More-specific information could also be important to assess the share of the different kinds of forest losses, such as due to fires, expansion of agriculture or urban areas, harvesting, etc.

TABLE 19: General forestland asset account for a hypothetical area and one accounting period

	Forestland (ha)
Opening stock	59,498.37
— Additions	1,554.21
— Reductions	3,118.32
Closing stock	57,934.26

The forest asset extent accounts could also measure the dynamics of different forest types. For instance, a distinction could be made between broad-leaved, mixed, and coniferous forest; natural and cultivated forest; protected and non-protected, etc. Compiling the forest accounts in such a way that data are organized per geographical units is particularly useful. The advantages of such an approach are related to the local nature of forest management measures, suitability of policy decisions, and assessment of ecosystem service flows. In this respect, the information given in Figures 8C and 8D is useful to exemplify the importance of partitioning the study area into smaller regions. Figure 8C is the digital elevation model of the region and allows partitioning the area in altitudinal strata. Figure 8D partitions the area in arbitrarily defined grid elements. In real applications, the partitioning can be made in accordance with criteria like administrative units, water catchments, territorial planning units, etc.

Table 20 presents the results of using the digital elevation model from Figure 8C to assess changes in forestland during the accounting period within different altitudinal strata. Following this approach may be particularly useful in regions where altitude is related to forest functions like flood protection, soil conservation, water cycle regulation, etc. The digital elevation model allows users to link the information on forest dynamics to other topographical variables like slope and aspect. The data in Table 20 show that the intensity of additions and reductions with respect to the opening forestland stock was not equally distributed across the study area. Forestland reductions were greater than additions in three out of four altitudinal ranges.

TABLE 20: Forestland asset accounts by altitudinal range (hectares)

	Altitude (meters above sea level)				
	0 – 500	500 – 1500	1500 – 2500	> 2500	TOTAL
Opening stock	10,396.89	10,920.06	17,102.52	21,078.9	59,498.37
— Additions	244.17	311.04	408.6	590.4	1,554.21
— Reductions	572.58	273.87	1,186.65	1,085.22	3,118.32
Closing stock	10,068.48	10,957.23	16,324.47	20,584.08	57,934.26

Table 21 presents data on forestland stocks when the study area is partitioned according to the grid shown in Figure 8D. This gridded partition analysis reveals more details at a spatial scale that is closer to the decision and planning capabilities of subnational authority levels.

TABLE 21: Forestland assets per grid units according to the partition presented in Figure 8D

	Grid unit reference number								
	u4	u5	u9	u10	u13	u14	u15	u16	u17
Opening stock	4,531.05	3,412.35	4,152.24	1,683.72	1,953.72	7,448.22	2,599.29	106.92	1,955.07
Additions	91.26	94.41	149.04	85.32	42.57	192.15	76.5	41.58	84.33
Reductions	214.56	148.95	215.19	15.66	179.19	432.27	151.83	8.91	38.25
Closing stock	4,407.75	3,357.81	4,086.09	1,753.38	1,817.1	7,208.1	2,523.96	139.59	2,001.15
	u18	u19	u20	u21	u22	u23	u24	u25	TOTAL
Opening stock	4,979.61	8,809.47	7,778.88	108.9	3,719.79	5,382.99	694.44	181.71	59,498.37
Additions	66.06	221.04	198.63	0	19.44	174.15	0	17.73	1,554.21
Reductions	84.87	650.07	373.68	0	242.73	358.29	0	3.87	3,118.32
Closing stock	4,960.8	8,380.44	7,603.83	108.9	3,496.5	5,198.85	694.44	195.57	57,934.26

Indicators of forest condition

Together with reporting opening and closing stocks and the source of additions and reductions in forestland cover, it is important to include an assessment of relevant characteristics of the forest ecosystem conditions in the forest accounts. The selection of forest condition characteristics should be focused at monitoring the capabilities of forest ecosystems to provide ecosystem services. The ecosystem characteristics to be considered in such an assessment and the suitable indicators for evaluation are region-specific. They should reflect the priorities and sensitive issues of each region. Table 22 presents a short list of common characteristics in the assessment of forest ecosystem condition along with a number of proposed indicators and potential data sources.

TABLE 22: Parameters of forest ecosystem condition, indicators, and possible data sources

	Indicator/unit	Data source
Defoliation	Litter fall measurements (kg)	1
	Leaf Area Index (LAI) based indicator	
Forest health	Presence of pathogens and plagues	1
	Status of bark	
	Mortality rate	
Forest fires	Burnt area	1, 2
Fragmentation	% of forest area in categories (core, interior, connected, patchy)	2, 3, 4
	Effective mesh size	
	Size of forest fragments	
	Length of fragment edge	
Aerosol pollutants	Ozone concentration	6**
	Nitrogen deposition	
	Sulfur deposition	

** ICP-Forests in Europe and FHM (http://fhm.fs.fed.us) and FIA (http://fia.fs.fed.us) programs in the United States gather various forest health indicators. One point of interest is the assessment of the effect of air pollutants.
Data Sources:
1. Forest inventories and forest statistics (including FRA and other FAOSTAT statistics)
2. Spaceborne remote sensing
3. Airborne remote sensing
4. LC/LU data and maps
5. Non-forest statistics

An important indicator of forest health and vitality is defoliation. Certain regions have monitoring networks in place where several indicators of forest health are constantly measured. The magnitude of defoliation is one of those indicators and is commonly measured by weighing the leaves collected in litter traps. At larger scales, monitoring the trends in Leaf Area Index (LAI) can be a useful proxy for quantifying defoliation. LAI is defined as the half the ratio of the area of leaves to the forest area. Estimates of LAI can be derived from RS imagery, such as MODIS LAI product (https://lpdaac.usgs.gov/products/modis_products_table/mod15a2), Geoland2 (www.geoland2.eu), and Global Land Surface Satellite product (http://glcf.umd.edu/data/lai/).

Forest fires can be a major threat to forest ecosystems' integrity and functioning. Although several regions have efficient systems for detecting and quantifying the extent of forest fires, the effect of these events on forest ecosystems in large regions of the world is not well known. Complementary information on the temporal and spatial patterns of forest fires can be derived from RS, particularly from specially designed products such as the MODIS burned area product (MCD45A1).

Deforestation, urbanization, agriculture expansion, extreme events, and other alterations of forest ecosystems may cause reductions in the forest stocks. Beyond the physical reduction in the stocks, these alterations lead to forest fragmentation. Forest fragmentation can be thought of as a break in the continuity of forest ecosystems. Fragmentation has multiple effects, including changes in ecological processes, reduction in biological diversity, the spread of invasive species from disturbed edges, and reduction in the attractiveness of forests for recreation activities. In the framework of forest accounting, forest fragmentation can be thought of as a source of variation in the capability of forests to provide ecosystem services.

Various indicators of forest fragmentation exist. A common approach is to track the mean size of forest patches or fragments and the length of the edge of the patches. Alternatively, the studied region can be represented as an arrangement of cells (grid), where each cell is labeled as forest or non-forest. The forest cells can then be classified based on the number of surrounding cells that are also labeled as forest. The result of this second approach is the calculation of the number of forest cells as core, interior, connected, or isolated forest cells. Other approaches include the effective mesh size and the degree of landscape division. The former represents the size of the areas when the region under study is divided into areas with the same degree of landscape division; the smaller the value, the greater the fragmentation. The degree of landscape division is the probability that two randomly located points in the studied area fall in the same forest patch.

Tables 23 and 24 present the values of a number of fragmentation indicators for the hypothetical example depicted in Figure 8. The comparison of the values in both tables shows the importance of the size of the area units (or spatial scale) chosen for the assessment of forest fragmentation. The subdivision of the study area into four areas using altitudinal strata results in large spatial areas where the effect of changes in forest cover is hardly reflected in the values of fragmentation indicators. Conversely, the values in Table 24, which are based on the smaller grid units from Figure 8D, show the forest cover dynamics more clearly and support interpretation of the ecological and policy-related implications of changes in forest cover.

TABLE 23: Indicators of forest fragmentation at the beginning and end of the accounting period for four altitudinal strata of the studied region

Altitude	Beginning of the period				End of the period			
(meters above sea level)	Average fragment size	Average edge length	Effective Mesh Size	Degree Landscape Division	Average fragment size	Average edge length	Effective Mesh Size	Degree Landscape Division
0 – 500	8.2	1242	926.5	0.915	7.8	1247.8	827.8	0.922
500 – 1500	7.7	1570.3	860.4	0.923	7.7	1593.9	667	0.941
1500 – 2500	19	1968.8	1206.8	0.932	17.5	1933.3	976.1	0.942
> 2500	22.8	2371.9	2246.9	0.904	21.8	2368.7	2151.8	0.905

TABLE 24: Indicators of forest fragmentation at the beginning and end of the accounting period for different units representing grid elements in which the studie area was partitioned

	Beginning of the period				End of the period			
Unit	Average fragment size	Average edge length	Effective Mesh Size	Degree Landscape Division	Average fragment size	Average edge length	Effective Mesh Size	Degree Landscape Division
4	33	3,635.4	3,963.9	0.142	35.7	4,076.2	3,593.8	0.201
5	10.3	1,562.5	852.1	0.757	10	1,568	827.5	0.76
9	14.1	2,067.7	425.8	0.901	13.3	2,002.5	383.2	0.91
10	12.7	1,576.2	306.4	0.827	13.5	1,646.2	377	0.795
13	90.7	5,687.7	842.9	0.578	74.4	5,258.4	584	0.686
14	32.5	2,941.1	1,201.7	0.843	30.3	2,909.3	1,064.7	0.856
15	11.6	1,487.9	435.1	0.837	11.1	1,491.5	390.7	0.85
16	1.6	487.3	3.8	0.975	2	513	15.1	0.917
17	8.4	1,175.8	173.7	0.915	8.7	1,216.2	191.9	0.908
18	10.1	2,011.7	1,307.2	0.741	9.9	1,989.8	1,122.5	0.777
19	19.1	2,023.2	4,141.8	0.541	18.5	2,121.1	3,647.8	0.576
20	27	2,629.4	2,681.6	0.664	25.5	2,599	2,407.8	0.691
21	1.2	383.9	3.4	0.969	1.2	383.9	3.4	0.969
22	8.7	1,111.6	942.3	0.748	8.1	1,120.7	862.4	0.755
23	10.9	1,934.9	751	0.865	10.4	1,925.1	689.5	0.872
24	3.2	796.7	31.2	0.955	3.2	796.7	31.2	0.955
25	3.6	787.5	27.4	0.862	3.7	793.2	26.6	0.875

5.3 Compiling measures of ecosystem service flows

Compiling the physical flow accounts requires measurement of the flows of forest ecosystem services from the natural system to the economy in physical units. Since there are many different forest ecosystem services, it is difficult to set a generic measurement approach for quantifying these flows. Table 25 presents a series of possible indicators for the services associated with forest ecosystems. The list is general and, as mentioned earlier, the final list of indicators and data sources should be a response to national priorities, critical policy-related topics, and data availability.

For a number of ecosystem services, especially regulating ones, the measurement of physical flows will be based on estimates that emerge from biophysical models—for example, of soil retention, water regulation, and carbon sequestration. These models require the use of various parameters that relate to the nature of the ecosystem, including relatively fixed factors such as slope, altitude, and soil type and variable factors such as rainfall and tree density.

Overall, however, there is likely to be a degree of uncertainty in the models, especially if the parameters are not well calibrated to the area under investigation. Further, the relationships between parameters of ecosystem condition and the flows of ecosystem services are likely to be non-linear—that is, the flows of services will vary according to the relative condition of the ecosystem. In developing estimates for ecosystem services using models, it is important to be aware of these issues. Further discussion on this is presented in SEEA EEA Chapter 5.

TABLE 25: Typical indicators and data sources for estimating ecosystem services

	Indicator(s)/unit	Data source
Provisioning services		
Timber	Harvested timber (m^3; m^3/ha)	1, 3, 5
Firewood/charcoal	Volume (m^3)	1, 4, 5, 6
NTFP	Volume (m^3); Weight (kg; ton);	1, 4, 5, 6
	Number of units	
Genetic material	Composition	6
	Diversity	
Grazing	Number of animals in silvo-pastoral system	6
	Weight units of produced animal product	
	Energy uptake	
Regulating services		
Atmospheric/climate regulation	Net carbon storage (gains-losses)	2, 6, 7
Water flow regulation	Canopy cover fraction in recharge areas	2, 6, 7
	Average daily and annual water flow in rivers	
	Cover in strategic locations (floodplains, steep slopes, wetlands, etc)	
Water cycle regulation	BOD	2, 6
	Turbidity in waterways	
Pollination	Abundance and variety of pollinator species	5, 7
Soil retention and formation	Erosion rates	7
	Cover (or bare soil) fraction in vulnerable areas	
	Turbidity in waterways	
Cultural services		
Recreation	Number/area of national parks	5, 7
	Area of parkland within cities	
Information and knowledge	-	
Spiritual and symbolic	-	

Data Sources:
1. Forest inventories and forest statistics (including FRA and other FAOSTAT statistics)
2. Spaceborne remote sensing
3. Airborne remote sensing
4. LC/LU data and maps
5. National accounts production data
6. Non-forest statistics
7. Other spatio-temporal datasets

Provisioning services

A substantial portion of the flows related to forest provisioning services is accounted for in the SNA. Yet gathering comprehensive datasets on these flows is not an easy task, especially when following a resource-based approach and if trees outside the forest are considered as sources of timber and firewood. The availability of data on non-timber forest products varies considerably among regions. Depending on the relevance and the market value of NTFPs, some estimates of the flows of these products may be derived from forest or economic statistics. Products like mushrooms, tree nuts, cinnamon, understory plants like xate (*Chamaedorea* sp), and ferns might be registered as market goods. Household surveys can also provide valuable information on the use of NTFPs, especially in rural environments. Data on grazing associated to forest may be obtained in agriculture or livestock surveys and household surveys. Considering silvo-pastoral and agroforestry systems (like the *dehesas* in Spain and Portugal) as classes when elaborating land cover/use maps can be an important input to quantifying and localizing the flows related to these kinds of integrated production systems.

Regulating services

Accounting for forest regulating services requires a more diverse range of methods and data sources. The measurements and modeling schemes often encompass such disciplines as hydrology, physics, edaphology, and geostatistics. As such, incorporating these flows in the forest physical accounts requires the integration of multidisciplinary teams and interinstitutional collaboration.

There is a global concern for quantifying the role of forests in the overall carbon balance. In this respect, estimates of carbon storage in forests, carbon sequestration, the effect of land use change, and deforestation are all relevant components within forest flow accounts. In addition, the recent development of carbon markets will allow for this flow to be expressed in monetary terms too.

Field surveys for measuring carbon sequestration follow very much the methodological and statistical principles of forest inventories; their detail and scope is, however, more comprehensive. They aim at measuring different carbon pools both above and below ground. Live and dead plants in the different vertical layers of the forest canopy are included as well as the soil. In measuring the different elements of the forest profile, the emergence of terrestrial LiDAR scanning systems is in full development in recent years. As for accounting for urban trees, McPherson et al. propose a methodology that combines field surveys and RS. FRA data have also been used for estimating carbon gains across the European Union.

Satellite RS can be exploited to support estimates of atmospheric carbon capture by forests. The possibilities include the RS-based land cover classification for segmenting the forest in homogeneous strata prior to field surveys and modeling approaches where forest productivity is derived from energy reflectance and ancillary data.

Regarding the role of forestland in the regulation of the water cycle, a suite of modeling alternatives is available to estimate surface (and sometimes groundwater) flows. Specific examples are the Soil and Water Assessment Tool model (and its implementation in ArcGIS–ArcSwat), TopModel (implemented in GRASS GIS and the topmodel R package), and MIKE-SHE.

Prevention of soil erosion is one of the most important ecosystem services of forests. Soil erosion reduces the land's productivity potential, increases sedimentation in waterways, increases the risk of landslides and floods, and increases the vulnerability of people to extreme climatic events. Indicators related to this ecosystem service can focus on the erosion itself (that is, measuring or simulating the volume of eroded soil for different scenarios of landscape configuration) or on the impact in water flow and quality. The classical way of modeling erosion is based on the Universal Soil Loss Equation (USLE). This estimates average annual soil loss (A) as the multiplication of five factors: a rainfall and run-off factor (R), a soil erodability factor (K), a slope factor (LS–length and steepness), a crop and cover management factor (C), and a conservation practice factor (P). The effect of forest cover on soil erosion in a water catchment can be assessed by replacing the C factor with alternative land cover classes. Improvements of USLE have resulted in alternative models; notably, the Water Erosion Prediction Project (WEPP), which has been implemented in software tools like GeoWEPP (http://geowepp.geog.buffalo.edu/).

A great deal of eroded soil ends up in stream channels and causes sedimentation and turbidity. Moreover, soil erosion causes an increase of organic matter in water, which in turn boosts the oxygen demand. These effects can be monitored through common indicators of water quality such as turbidity and biochemical oxygen demand.

Cultural services

Statistics on the numbers of visitors to forests are the primary data source for assessing the recreational value of forest ecosystems. Whenever the assessment of recreational value is desired for large areas (such as country level), on-site surveys are likely not available. In that case, modeling the number of visitors is an option for determining the magnitude, origin, and destination of visitors to forests and green urban areas. Factors like size of forests, quality of the site, distance to human dwellings, and conditions of the road network have often been found to be significant determinants of numbers of visitors for recreation.

Applying these factors in modeling schemes lends itself to GIS-based analysis in which distance over road networks can be estimated, road quality classes can be expressed in friction values (that can be related to travel time and cost), and location and size of forests and urban areas can be modeled as polygons or raster layers. A simple modeling scheme can be based in a gravity model where the flow of visitors is assumed to be directly proportional to the size of forests and the population of potential visitors and can be inversely proportional to the square of distance between forests and human dwellings. In accounting for distance, current GIS tools (like ESRI's ArcGIS Network Analyst extension and the tools for network analysis in GRASS GIS) allow the use of distances over a road network instead of Euclidian distances. Publicly available datasets like Open Street Map (www.openstreetmap.org) can be useful in obtaining road network data.

In addition to these modeling alternatives, it is important to underline recent modeling efforts toward the description of ecosystem services such as Artificial Intelligence for Ecosystem Services (ARIES, http://www.ariesonline.org) and Social Values for Ecosystem Services (SolVES, http://solves.cr.usgs.gov/). ARIES is a modular set of deterministic and Bayesian modeling tools including, among others, estimates on carbon sequestration and storage, sedimentation, and recreation. SolVES is a GIS-based tool to quantify the perceived social values of ecosystem services. Thus the system relies on community-based evaluation of the non-monetary value of environmental services.

5.4 Challenges

Despite the numerous datasets and methods devoted to the study of forest resources and services, the timely and consistent acquisition of data and its coupling to economic statistics is a major challenge for countries compiling forest accounts.

RS developments of vegetation and modeling of ecosystem services are promising alternatives to ensure coverage of large areas at short time steps. RS data can be especially useful when searching for indicators of non-measured variables or when registering the conditions of non-surveyed regions. However, it is important to note that using RS data is not free of errors, and the reliability and comparability of measurements depends on many factors, including atmospheric conditions, cloudiness, slope and shadow effects, illumination conditions, etc. There are also particular difficulties in translating information about a three-dimensional world into two-dimensional datasets and maps. Therefore, exploring different methods for data processing and searching robust validation sources are important characteristics for incorporating RS in a forest accounting scheme.

Forest accounting is focused on describing the interactions between society and the natural system. Thus data comparison across time is of paramount importance. In this respect, the use of different criteria and methods for updating forest inventories, land cover maps, household surveys, census, or other essential datasets hampers the identification of trends and the evaluation of the effects of policies (or the lack of effects).

6. Compiling monetary accounts for forests

In order to aggregate measures of forest resources and ecosystem services and then compare them with other economic estimates, such as financial costs, a single measurement unit of currency is needed. Monetary valuation provides a straightforward decision-making metric that is widely used and accepted in decision-making processes and that facilitates integration with the standard economic accounts of the SNA.

Putting a monetary value on forest resources and ecosystem services also supports, for example, raising awareness of the relative importance of forests and mainstreaming their value into decision making, comparing the economic importance of different asset types (including forests), and informing economic decisions about different land use choices (through cost-benefit analysis, for instance).

Notwithstanding these merits, valuation of forest resources and ecosystem services can be challenging and requires a number of special considerations for accounting purposes. Most importantly, these services can only be valued through the benefits they provide to humans. For the forest resources that enter markets—notably, timber and wood products—market prices can be observed or imputed and used to value the benefits and the relevant ecosystem services. However, the benefits from the use of many other forest ecosystem services, mostly non-provisioning services, are not exchanged in markets and do not have market prices that can underpin valuation.

6.1 What to value?

Forest ecosystem services can be valued through the benefits they provide for humans. Put differently, for accounting purposes it is relevant to apply the notion of a chain of values in which ecosystem services contribute or are inputs to the value of benefits. These benefits consist of different types of goods and services that directly generate utility and alter human welfare. Three broad groupings of goods and services can be identified:

- Intermediate goods and services that are produced within the economy and serve as inputs to the production of other goods and services—the outputs of agriculture and forestry are good examples

- Goods and services consumed directly by households from the environment and hence represent final goods and services that would be considered part of economic production in the SNA—household collection of mushrooms and berries from forests are examples
- Goods and services outside the production and income boundary of the SNA that are either used, perhaps unknowingly, by economic units within their production processes (such as soil retention and water flow regulation by upland forests) or consumed by households or society as a whole (such as amenity benefits from scenic landscapes and carbon sequestration services)

The values of these benefits may be captured in standard economic accounts and, if so, techniques can be applied to estimate the value of the associated ecosystem service—that is, the value of the contribution of the ecosystem to the generation of the benefit. Where the value of the benefit is not captured in standard economic accounts, other techniques to estimate its value and that of the associated ecosystem service must be found.

The ecosystem services just described are commonly referred to as final ecosystem services since they reflect the point of interaction between ecosystems and economic units and people. Underlying these final ecosystem services is a web of other ecosystem interactions and processes. In theory, it would be possible to attribute the value of final ecosystem services further down the "ecological" production function, but this step is not normally undertaken so it is not discussed further here.

Generally speaking, the value of forests can be considered in terms of direct use values (through their consumptive and non-consumptive uses), indirect use values (through contributions to other goods and services with direct use value), or non-use values (any intangible benefits people enjoy) attached to them. Each type of value will have a connection to different types of benefits and hence to the underlying ecosystem services.

Table 26 gives a condensed overview, in the first two columns, of the connections between forest benefits and ecosystem services. It is important to recognize that there can be different beneficiaries of these services. The beneficiaries include those in the forestry industry (logging companies, wood production) and those in other industries (such as hydropower companies, agricultural producers, municipal water supply, the tourism sector). The beneficiaries may range from local (forestland user, downstream municipality) to national and even global levels.

TABLE 26: Overview of forest ecosystem services and benefits and their inclusion in the SNA

<table>
<tr><td colspan="4">Key: (P) – Provisioning services; (R) – Regulating services; (C) – Cultural services</td></tr>
<tr><th rowspan="2">Forest Ecosystem Services</th><th colspan="2" rowspan="2">Forest Benefits</th><th>SNA</th></tr>
<tr><th>Production Account</th></tr>
<tr><td>timber (P)</td><td>timber</td><td rowspan="3"><u>market benefits:</u> market goods and services produced by forest activities</td><td rowspan="3">explicitly measured if resulting in market-production (sale/barter) or production of goods for own final use</td></tr>
<tr><td>firewood/charcoal (P)</td><td>wood-based energy</td></tr>
<tr><td>other NTFP (P)</td><td>food, fodder, medicine</td></tr>
<tr><td>carbon storage/ sequestration (R)</td><td>climate regulation</td><td></td><td>not included</td></tr>
<tr><td>genetic material (P)</td><td>product development</td><td rowspan="10"><u>quasi-market benefits</u>: contribute to the production of market goods and services produced by other economic activities</td><td rowspan="10">implicitly measured through the value of non-forest market-production (sale/barter) or production of goods for own final use</td></tr>
<tr><td>biomass for grazing (P)</td><td>livestock production</td></tr>
<tr><td>pollination (R)</td><td>agricultural production</td></tr>
<tr><td rowspan="2">water flow regulation (R)</td><td>flood protection</td></tr>
<tr><td rowspan="2">hydro-power production</td></tr>
<tr><td rowspan="2">soil retention and formation (R)</td></tr>
<tr><td>sedimentation control</td></tr>
<tr><td>water cycle regulation (R)</td><td>(drinking) water supply</td></tr>
<tr><td>recreation (C)</td><td>tourism</td></tr>
<tr><td>information and knowledge (C)</td><td>research/ education</td></tr>
<tr><td>spiritual & symbolic (C)</td><td>cultural heritage, identity, spiritual/ religious functions</td><td rowspan="2"><u>non-market benefits</u>: do not contribute to goods or services traded at markets</td><td rowspan="2">not included</td></tr>
<tr><td>non-use (C)</td><td>existence/ bequest/altruist</td></tr>
</table>

6.2 Market, quasi-market, and non-market benefits

In addition to the categories just described, benefits may be grouped according to different approaches to their valuation: market, quasi-market, and non-market benefits. This breakdown refers to their linkages to market goods and services and to the extent to which they are included in the SNA or SEEA Central Framework, which is summarized in column 4 in Table 26. As shown in section 6.4, each type of benefit requires consideration of different valuation methods.

Market benefits

Market benefits are those goods and services produced by forest-based activities that can be traded in markets and thus for which there is a market price. They can be linked to two main types of ecosystem services:

- *Provisioning services with a direct consumptive use value:* These ecosystem services contribute to the production of private goods that can be traded in markets, such as timber, wood-based energy from charcoal and firewood, or food, fodder, and medicine from NTFPs. The private goods are explicitly measured as forest-related benefits in the SNA if they result in market production or production/consumption on their own account.
- *Some regulating services (primarily relating to climate regulation):* Some ecosystem services, such as carbon sequestration, may contribute to the production of market benefits under specific institutional arrangements. Examples are some payments for ecosystem services (PES) schemes or carbon markets that assign property rights to the benefits and generate tradable units, such as carbon offsets. Although transactions in these markets should be recorded following the SNA, they will not be recorded as transactions in ecosystem services but rather in terms of either financial assets and liabilities or transfers between economic units, depending on the nature of the PES scheme that has been established.

Quasi-market benefits

Quasi-market benefits are those provided by ecosystem services that in turn contribute to the production of market goods or services by other economic activities—for example, the contribution of the water-regulating services of forests to the production of hydropower. Although these contributions are not explicitly measured and valued, they are implicitly included in the market value of these goods and services and hence they are implicitly accounted for in the SNA. Special valuation methods are needed to reveal their values and to report them in forest accounts. Three broad types of ecosystem services contributing to quasi-market benefits can be distinguished:

- *Substitutable ecosystem services that are inputs to non-forest production:* These services can include water cycle regulation increasing drinking water quality (reducing the need for water treatment), water flow regulation providing water to agriculture (reducing irrigation needs), and soil retention control reducing sedimentation (reducing dredging or protection of infrastructure needs).
- *Complementary ecosystem services that are inputs to non-forest production:* These services include genetic material contributing to the development of new products, pollination, or grazing services for agricultural and livestock production or water flow regulation for hydropower production. The differentiation between substitute and complementary inputs depends on the availability of alternative production inputs or technologies.
- *Attribute of a heterogeneous non-forest market good:* These ecosystem services are recognized in cases where there is a more complex market good that involves interaction with the environment and hence the ecosystem is one component or attribute in determining the value of the good. Examples include recreational services for a forest resort that contribute to tourism revenues and information and knowledge services from a unique forest ecosystem that attracts research and education activities.

Non-market benefits

Non-market benefits reflect inputs from forest ecosystem services to benefits that do not contribute to market goods or services.[13] In most cases the relevant ecosystem services are cultural ones with public good characteristics. These services include cultural heritage, local identities, and spiritual and religious functions from spiritual or symbolic services. Broadly speaking, they have non-consumptive use values and represent public goods mainly of importance at a local level.

Non-market benefits also include non-use values that cannot be attributed to specific ecosystem services. Examples of non-use values include bequest values (from knowing that future generations will have access to these ecosystem services), altruist values (from knowing that other people have access to these services), and existence values (from knowing that the ecosystem exists).

The value of these non-market benefits is not included in the SNA.

13 It is important to recognize that the use of the term “non-market” in economics differs from its use in national accounting. Here non-market is used in its economic sense to indicate that there is no exchange between economic agents (households, companies, etc). In national accounting, non-market refers to situations where the exchange of goods and services takes place at prices that are not “economically significant.” Examples of national accounts non-market pricing include government provision of health and education services.

6.3 National accounts valuation concepts and principles

General concepts

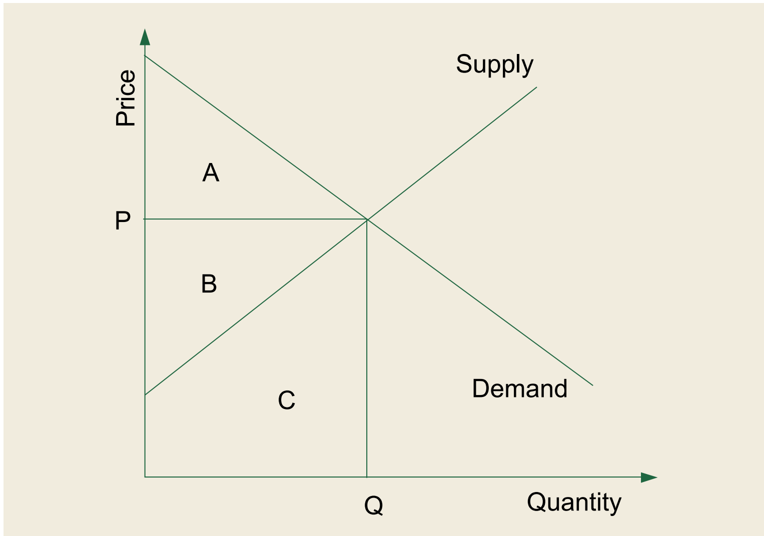
To ensure compatibility with SNA estimates, the valuation of forest resources and ecosystems needs to be based on the exchange value. This is the value at which goods, services, labor, or assets are in fact exchanged or else could be exchanged for cash (SNA 2008: 3.118). These values should be based on market prices for transactions—that is, money that willing buyers pay to acquire something from willing sellers (SNA 2008: 3.119). Where such prices are not available, valuation according to market price equivalents should be used to provide an approximation of market prices (SNA 2008: 3.123).

In neoclassical economics, exchange values result from the price (P) and the quantity (Q) exchanged at the equilibrium of supply and demand (see Figure 9). Without going into details, area A reflects the consumer surplus arising from a price lower than consumers' willingness to pay, which should equal their marginal utility gained from consuming one more unit of the service (as portrayed in their demand curve). Area B is the producer surplus arising from a price higher than the producer's willingness to accept, which equals their marginal production costs, C (as portrayed in their supply curve). The value entered into the SNA is P*Q or B+C in Figure 9. This means that A, the consumer surplus, is not included in SNA-based valuations.

Exchange values do not necessarily reflect social values. The measurement of social values is not standardized, but it plays a key role in the economic valuation of forest resources and ecosystems. Social values represent the full benefits that accrue to society, today and in the future, in terms of changes in welfare (or total economic value). Generally, social values would be estimated based on changes in both producer and consumer surplus (and thus include area A in Figure 9). Social values aim to capture the ecosystem services that never enter markets due to externalities or market imperfections.

Although these additional values are not captured using the standard valuation principles of the SNA, there is ongoing discussion, in the context of the SEEA EEA, of whether the concept of ecosystem services makes it possible to estimate exchange values for forest ecosystem services that are not directly traded in markets. A WAVES project will provide a paper on these conceptual issues in 2016. The real challenge from an accounting perspective is that many valuation methods that are applied aim to estimate a willingness to pay from changes of consumer surplus in different scenarios. Such values go beyond the exchange value concept by including consumer surplus, which would rather correspond to a social value concept. Therefore, matching valuation methods to the required valuation concept is a key issue for ecosystem accounting.

FIGURE 9: Consumer surplus (A), producer surplus (B), and production costs (C)



It has been argued that different prices may be recorded for the same market good according to the price function that arises in some particular market situations. Hence, depending on the market institutions and the level of price discrimination, prices need not be constant at P, as shown in Figure 9. Rather, they would vary with consumers' willingness to pay in order for the producer to "capture" the consumer surplus. Thus, in situations of very high degrees of price discrimination—that is, where there is customer specific pricing—consumer surplus would be eliminated and exchange values and welfare values would align. Since for many ecosystem services there are no observable markets, this potential alignment cannot be assumed.

Concepts in valuing ecosystem services at exchange values

Following the SNA, and as described in the SEEA EEA, exchange values for forest products and ecosystem services may be estimated in three ways:

- Market prices: Goods and services exchanged in markets can be valued based on their observed market price. Strictly speaking, market prices are defined as the amount of money that willing buyers pay to acquire something from willing sellers (SNA 2008: 3.119).
- Market-price equivalents: Goods and services not exchanged in markets can be valued by the prices of the same or similar products if this price is believed to be the price expected to be paid by market participants and if the additional market supply of these goods or services does not have any price effect.
- Cost of production: Goods and services can be valued by the sum of all costs of producing the good (for example, land rents, machinery, and labor costs).

Concepts in valuing assets at exchange values

Ideally, observable market prices should be used to value the stock of forest resources and forest ecosystem assets. According to the SNA (2008, 13.18), when estimating a current market price, a price averaged over all transactions in a market can be used if the market is one in which the items in question are regularly, actively, and freely traded. If market prices cannot be observed, an attempt has to be made to estimate prices.

For valuing forest assets, there are three options to estimate exchange values following the SNA (2008, Ch. 13.B) and SEEA Central Framework (ch. 5.4.3):

- Land values observed in markets: Where market prices are listed at regular intervals and for homogenous land types, relevant land prices can be used to value forest ecosystems (even if they are actually not traded) (SEEA CF 5.6).
- Written down replacement cost: The accumulated consumption of fixed capital can be subtracted from the current acquisition price of an equivalent new asset. When reliable and directly observed prices for used assets are not available, this procedure gives a reasonable approximation of what the market price would be were the asset to be offered for sale. Since forestland is not depreciable, however, this method is not appropriate for forest valuation.
- Net present value: This involves the discounted value of future returns from forest resource stocks or the discounted value of all flows of ecosystem services from forests (see Box 18).

BOX 18: Calculating net present values

The general aspects for calculating a NPV are discussed in detail in SEEA Central Framework 5.4.4 and Annex A.5. The main elements are as follows.

Current and expected returns on resource stocks or forestland: Returns are defined as the economic rent or surplus value that is attributable to the timber resource or ecosystem service. For resources, a number of standardized approaches can calculate resource rents (such as residual value, appropriation, and access price method; see SEEA CF, section 5.4.5). These methods ensure that net returns are estimated and also that the user costs of fixed capital are deducted. For ecosystem services more broadly, a number of valuation techniques can be applied.

To value future flows of resources and ecosystem services, the expected returns are important. These are determined by the expected quantity of resources to be extracted or use patterns, future extraction and management costs, and resource prices. Where these are highly volatile and uncertain, it is often assumed that these are constant, based on past extraction patterns.

Time span and expected extraction or use pattern: Estimates of the asset life are required to provide the time frame over which the NPV is to be calculated. Generally, any returns beyond 20 years do not affect the NPV, but this depends on the choice of the discount rate. Where future extraction or use patterns are known (for instance, resources are only to be extracted after 10 years), these need to be accounted for. Otherwise, current extraction and use patterns can be assumed to remain constant. If there is unsustainable use of a resources, resulting in depletion or degradation, the resulting impact on supply of forest resources or ecosystem services should be reflected in the resulting calculations.

Discount rate: To value future returns at their present value, the returns need to be discounted. A discount rate expresses time preference (that is, how far someone is willing to trade off income in the present with income in the future). The higher the preference for current income, the higher is the discount rate and the less valuable is income earned in the future. This can also represent risk aversion. The SEEA Central Framework recommends a market-based discount rate that is equal to the assumed rate of return on produced assets. This allows the estimation of exchange values that can be integrated with other national accounts balance sheet values and compared with measures of production and income, for example for estimating productivity. For other analysis, however, it may be relevant to apply social discount rates that take long-term values to society into account more explicitly. The SEEA Central Framework Annex A5.2 explains relevant considerations.

Note that where the future returns are estimated in terms of constant prices (that is, it is assumed the resource price remains the same into the future), the discount rate applied should be in real terms—that is, after taking out the effect of inflation. Where forecasts of future prices are incorporated, then a nominal discount rate should be applied.

For the valuation of timber resources, the recommended approach is the use of NPV, since market transactions or a set of acquisition prices are hardly observed. This is in line with the SEEA Central Framework, which highlights NPV for the valuation of environmental assets while recognizing the market price principles of the SNA.

For the valuation of forestland, other considerations need to be taken into account. In principle, the value of the timber resources should be considered separately from the land "under" the timber resources themselves. This recognizes that, for accounting purposes, the timber resources may be depleted while the land itself remains. Tracking these different but combined assets is therefore conceptually ideal.

The estimation of the value of forestland may, however, be challenging. In some cases, when the only relevant income stream is from harvesting timber, the value of the land itself may be very low and hence the value of forestland and of timber resources are effectively the same. On the other hand, where forestland can be converted to alternative land uses—for example, for agriculture or housing—the market value of the land may be quite distinct from the value of the timber resources since other potential income streams might be considered. In some countries there are active markets in forestland, and this information can be used in determining appropriate values.

Where forestland values are not directly observed (for instance, via land markets), estimating the benefits from alternative land use can be an alternative valuation method. Such an "opportunity cost" approach is an attractive solution if the benefits from alternative land uses are easy to compute—for example, when agricultural price and production data are available. This valuation approach assumes that land users only forgo benefits from alternative uses if the use of the land as forest provides them with benefits that exceed the opportunity costs, in which case the valuation represents a lower limit on the value of the forestland.

Note that the use of these values for accounting purposes must take into account the likelihood of the alternative uses. Thus if there is no prospect of the forest being used in other ways (for example, due to existing legislation), then the value of alternative uses is an interesting calculation for analysis but not appropriate for accounting.

Forestland may also be valued with respect to ecosystem services. In this case it is relevant to include not only the future streams of value associated with flows of timber but also the NPV of flows of other ecosystem services being supplied by the forestland. However, the potential trade-offs between different ecosystem services (for instance, between timber extraction and carbon storage) need to be considered when making projections or assumptions about future flows of ecosystem services. Further, the value of alternative land uses, as just described, should be considered in addition to the NPV of ecosystem services.

6.4 Methods for valuing ecosystem services and benefits

A number of well-established valuation methods have evolved and been widely applied in environmental and ecosystem service valuation. Most of these techniques are, however, not explicit about how consistent they are with the exchange or social value concept. Depending on the framing and design of the valuation exercise, these methods can derive values that are compatible with the SNA and SEEA EEA.

Further, in both design and application the methods are often not clear as to whether the focus of valuation is the benefits being derived or the ecosystem services that are contributing the benefits. This section gives a brief overview of different methods and the following section discusses the application in an accounting context.

When undertaking non-market valuation using the techniques discussed here, considerable biases and uncertainties may affect the results. These have been discussed in detail in the valuation literature, and the discussion certainly raises material issues to be considered in undertaking valuation and in the interpretation of results. An introduction to these issues is provided in SEEA EEA Chapter 5.

It is recognized that the methods described in this chapter focus only on the estimation of values in monetary terms, and that methods to undertake valuation in non-monetary terms are used, for example by ranking ecosystem services in terms of relative importance. Generally, the accounting frameworks described in the *Sourcebook* can support and organize the information required for either monetary or non-monetary valuation.

Market price–based valuation methods

These methods are based on actual market data (quantities, prices, costs), which are usually relatively straightforward to obtain. The methods can normally only be applied for market benefits and to a limited extent for ecosystem services that are substitutes for inputs into production.

Unit resource rent methods

Values of ecosystem services can be calculated based on market price data for forest resources and provisioning services directly sold and brought at a market, adjusting for the costs of extraction including costs of fixed capital. There are three main approaches to estimating resource rents, and in principle all should yield the same result.

- *Residual value*: Under this method, resource rent is estimated by deducting user costs of produced assets from gross operating surplus after adjustment for any specific subsidies and taxes.
- *Appropriation method:* Resource rent is estimated using the actual payments made to owners of forestland.
- *Access price method:* Resource rent is based on payments for the purchase of licenses or quotas to gain access to a forest area.

Where market prices include rents for labor and other assets, these should be deducted to calculate the rent for the forest resource or ecosystem services only. Valuation based on these rents needs to reflect any unsustainable use (for example, overharvesting of forest resources) or ecosystem degradation.

Cost-based methods

Values of ecosystem services can be estimated through the costs of replacing them or the costs of losing them. The latter are also called "costs of inaction."

- *Replacement costs* value ecosystem services through the costs for replacing an individual service by a produced facility that provides the same service, such as filtering water in a water treatment plant, dredging to remove soil sedimentation, or building landslide protection mechanisms. All of these are services that can be provided by ecosystems.

- *Damage costs* value forest benefits by the costs of losing ecosystem services. Examples include damages due to increased flooding from less-regulated water flows or to landslides caused by soil erosion.

Revealed preference methods

These methods seek to reveal values through observations from market transactions by trying to single out the price effect of the ecosystem services. These can be used for valuing quasi-market benefits.

- *Production/cost/profit function methods* estimate the value of an ecosystem service by recognizing it as an input into the production of a market good or service (such as pollination services) using relevant production, cost, or profit functions or productivity changes. These methods require an understanding of the linkages between the ecosystem service and the production of the final output.
- *Hedonic pricing methods* derive the implicit price for an ecosystem service by modeling land values on a set of explanatory variables (characteristics of the land), including ecosystem-related proxies. Hedonic pricing has been mostly applied in the context of well-established property markets to price characteristics such as cleaner air.
- *Travel cost methods* calculate the value of ecosystem services (mostly recreational) by the time and travel costs people incur to visit a forest area that provides these services.
- *Averting behavior methods* analyze individual choices to improve certain outcomes. From data on expenditures for certain measures (such as installing water filters to reduce pollutants in drinking water at home), the willingness-to-pay for an ecosystem service (water filtration, in this case) can be derived.

Stated preference methods

These methods derive values for environmental benefits by identifying people's preferences in hypothetical market contexts. Their main strengths as opposed to the other approaches is that they can be designed for any ecosystem services context and can also be used to value non-market benefits. At the same time, a number of concerns have been raised in applying these approaches in an accounting context.

- *Contingent valuation methods* are based on surveys asking people how much they would be willing to accept as a compensation payment for the loss of environmental benefits or how much they are willing to pay for improving environmental benefits.
- *Choice experiments* analyze decision-making processes from data related to people ranking of/choosing a limited number of hypothetical options. Each of these options is related to a number of choice attributes, including a monetary value (price, costs) and an ecosystem service supply level.

Benefit transfer

The methods just described can all be designed to estimate a range of different values and ecosystem services. Ideally, they would be implemented through the collection of data pertaining to specific ecosystem locations and/or services. Given the time and cost implications, and given the growing body of valuation studies, benefit transfer methods become more prominent. These support the use of information from one location or ecosystem in the valuation of similar ecosystems in other locations. Four benefit transfer methods are described here. Since various assumptions are needed to apply any of the methods, care should be taken in their application and in the interpretation of results.

- *The unit benefit transfer method* simply takes the unit value of forest benefits (per hectare, for example, or per person) from an original study as a reference value for the forest ecosystem to be accounted for and adjusts for the size or population.
- *Adjusted unit transfer methods* adjust the same unit value by controlling for economic conditions (such as living standards) or ecosystem characteristics (such as tree coverage).
- *Value/demand function transfer methods* apply parameters from an original study determining the importance of ecosystem characteristics though a demand or value function (such as to impacts of slope and rainfall on soil retention control values). These parameters are then combined with data from the forest ecosystem.
- *Meta-analytic function transfer methods* estimate such parameters for an aggregated demand or value function for a number of original studies. Then these aggregated parameters are combined with forest ecosystem characteristics.

To support benefit transfer work, and based on the growing number of valuation studies, a number of databases are being developed to support valuation. One example is the work of The Economics of Ecosystems and Biodiversity initiative (a database available at http://www.fsd.nl/esp/80763/5/0/50).

The use of benefit transfer techniques is likely a requirement for forest accounting purposes unless there are sufficient resources for direct, site-specific data collection. Consequently, since different benefit techniques are considered to be better or more complete than others, it is important that considerable care is taken in the application of methods to ensure that the assumptions made are reasonable in light of differences between sites. Further discussion of this issue is in SEEA EEA Chapter 5.

6.5 Valuation of forest resources and ecosystem services

Based on these valuation methods, forest resources and ecosystem services can be valued so as to account for flows and stocks in monetary terms. Table 27 gives an overview of how different resources and services can be valued. A number of academic case studies and project evaluation exercises have been applying these techniques.

TABLE 27: Forest benefits and valuation techniques

Forest Benefits	Valuation methods							
	Market price valuation		Revealed preferences			Stated preferences		Benefit transfer
	Unit resource rent	Cost-based	Production function	Hedonic pricing	Travel costs	CV	CE	
Market benefits								
Timber	X							X
Firewood, charcoal, and other NFTPs	X	X						X
Climate regulation and other regulating services (part)	X	X						X
Quasi-market benefits								
Substitute input in non-forest production		X						X
Complementary inputs in non-forest production			X					X
Attribute of a heterogenous non-forest market good				X	X	X	X	X
Non-market benefits								
Cultural benefits						X	X	X

Valuing market benefits

Ideally, forest accounts would identify three components of the value of forest goods and services.

- The *production value* is the total quantity sold or used times its unit value (P*Q or A+B in Figure 8).
- The *value-added* part of production value generated by forest ecosystem services is a portion of the production or extraction costs, measured as output minus all intermediate costs of production. This value is the contribution to GDP.
- The *resource rent* or in-situ value contributed by forest ecosystem services—the value of the product generated minus any production or extraction cost (A in Figure 8).

Often the resource rent and value-added part are calculated based on the production value (as in the residual value method), as this is easiest to derive or can be directly be observed. Generally speaking, market price valuation methods can be applied for the valuation of forest ecosystem services with market benefits so as to derive the production value, value-added, and resource rent (see Table 27).

Valuing timber

As timber is often traded at markets, the valuation of timber flows and stocks based on unit resource rents is relatively well established (see SEEA CF, chapter 5.8). Resource rent on timber can be derived as follows.

- *Appropriation methods:* In some instances resource rents rent can be estimated directly by using estimates of the stumpage price—that is, the amount paid per cubic meter of timber by the harvester to the owner of the timber resource (SEEA CF 5.380).
- *Residual value method:* In cases where such transactions cannot be observed because, for example, the forest operations are conducted in part by forest owners, it must be calculated. Resource rent can be derived as the gross operating surplus from the harvest of timber resources less the value of the user costs of produced assets used in the harvesting process (SEEA CF 5.378). For individual companies, stumpage value equals raw wood prices minus the logging, transportation, and stacking costs.

Using these resource rents, the stock of timber resources or future ecosystem service flow from the timber stock can be valued following three approaches.

- *The NPV approach* calculates the discounted value of the economic benefits from timber that will be generated over a defined time span. It may be implemented using the average stumpage price for all removals or by distinguishing stumpage prices for different timber species. It can further differentiate between different cutting ages for different timber species and the total area in age species age-class, while controlling for actual removals and natural regrowth.

- *The stumpage value approach* is a highly simplified version of the NPV approach. It multiplies physical stock with the average stumpage price of the timber removed. Where there is a market for standing trees, the stumpage values are directly observable. In the absence of such markets (or where market prices may be distorted), the stumpage value can be estimated. Under highly restrictive assumptions (that the discount rate equals the natural regrowth rate of the forest), this approach is the same as the NPV approach. This approach may be refined by applying the stumpage price for different species to the remaining stock of each species.
- *The consumption value approach* is a variant of the stumpage value approach, in which stumpage value is distinguished not only by species but by age or diameter class as well. The distinction between the two is that the stumpage approach uses the structure of fellings for weighting stumpage prices, whereas the consumption approach uses the structure of the stock.

Valuing firewood, charcoal, and other NTFPs

The resource rent generated by NTFPs is the production value minus its extraction costs, which is comparable to the stumpage value of timber. It is, in principle, the amount that someone would be willing to pay to rent the forest in order to have access to the product.

If these NTFPs are exchanged in formal markets and result in monetary transactions, they are reported in the SNA. Yet often NTFPs, especially in developing country contexts, are exchanged in informal markets or used to meet subsistence needs being produced or extracted for personal use (for example, collection of firewood from a nearby forest). The SNA has established principles for the inclusion of such non-monetary transactions, allowing three different approaches.

- *Unit resource rent approach:* Even if NTFPs are widely used for informal exchanges or personal consumption, market prices for the same or a very similar product can be observed nearby (buying charcoal at a local market, for instance). Local market prices for these goods may be used to value non-market production, taking care to account for regional variations in prices.
- *Replacement cost approach:* A variation of this approach is to value forest products at the cost of replacing them with close substitutes. For example, instead of eating bush meat, forest dwellers could buy other meat at a local market.
- *Production cost approach:* If there are no representative local market prices or close substitutes, the production costs of the product can be taken. Where labor is the most significant production cost, products may be valued at the opportunity cost of the time it takes to gather them. An average local wage can be used, adjusted for local and household-specific factors. Where significant additional non-

labor inputs are required, these should be included in estimating the production cost.

As a general observation, forest accounts have most often measured the physical quantities and production value of NTFPs but have not always calculated the value-added part or the resource rent. In many contexts, such as the collection of firewood or hunting, the primary input is “free” household labor without any cost expenditure being reported. In these cases, the distinction between total value-added and in-situ value is highly sensitive to the assumptions made about the opportunity cost of labor. Only when there is extensive commercialization of forest products do other costs, such as transportation, become potentially important. Often estimates rely on local surveys of household NTFP extraction and self-consumption and sales. These are then upscaled to a regional or even national level, assuming the same values across different communities or even regions. Although this is a practical approach, these values may differ substantially from the real, locally specific values. As the use and value of non-market forest products depends on many local factors that can vary enormously even within a region—such as the availability of forest products, alternatives available to local communities, opportunities for selling products in local markets, and local demand—locally differentiated values should be applied where possible.

Valuing climate regulation and other regulating services

Given the importance of carbon sequestration and storage for climate change mitigation, a number of market-based solutions are being discussed that would generate payment flows for the provision of such regulating services and thus turn them into market benefits (such as PES and trading schemes). Although the value of carbon stored in timber resources and in forest ecosystems is increasingly being considered, at the moment there are no commonly agreed accounting standards for its valuation. With an increasing number of countries interested in taking part in REDD+ activities, this becomes increasingly important. For the valuation of carbon-related ecosystem services (carbon sequestration and carbon storage), several different options may be possible.

- *Damage cost approach:* This approach estimates the costs of the global damage from climate change averted by reducing emissions by a unit (for example, a ton) of carbon. This value corresponds to a social value concept. Exchange values are unlikely to be equivalent to these costs. The U.S. government recently decided to use a range of estimates centered on $21 per ton of carbon dioxide (tCO2) in cost-benefit analyses.
- *Production costs approach:* The costs of avoiding climate damages can be estimated through the costs of climate change mitigation. These costs can be based on the production cost of reducing emissions

from deforestation and forest degradation—and most of all on the opportunity costs of not converting forestland into other uses . This estimate can serve as a lower-bound value, as any market price would need to be above these production costs. However, the link to the valuation of the specific ecosystem services needs to be determined.

- *Rents:* If market-based mechanisms are established, rents per land unit can be calculated based on the carbon sequestered and stored in above- and belowground biomass. Payment levels per unit of carbon could be based on one of the following:
    - *Carbon emissions tax:* If countries levy such a tax, the tax per emission unit can be used to value the carbon emission reductions through carbon sequestration.
    - *Price of carbon offsets:* Carbon markets are currently discussed for an international climate deal and future REDD+ mechanisms. There are already a number of voluntary carbon markets that trade carbon offsets. In 2011, carbon credits generated from REDD+ projects ranged between \$4 and \$11.5 per tCO_2 emission reductions over the whole project life span.
    - *Payments for emission reductions:* Carbon sequestration and storage could also be priced if payments were made to land users through direct transfers from a national or international climate fund, as is also being discussed as part of an international climate deal and REDD+ mechanisms.

With the growing application of markets or payments for ecosystem services for other regulating services (most prominently, water-related services), these could also be considered for accounting purposes. Nonetheless, using these values is problematic, as payments are often not outcome-based (conditional on the actual ecosystem services delivered) but rather activity-focused (conditional on a certain land use practice, which sometimes does not have a clear link to the ecosystem services to be provided), and there are large variations in payment levels depending on the location and purchaser.

Another example of ecosystem services that can form a forest-related market good is genetic material. Companies or research institutions pay for bioprospecting schemes that grant research institutions or private companies the right to use genetic resources. Despite being widely appraised in the 1990s as a potential market solution for conserving forest biodiversity, such payment schemes have found only limited application.

Valuing quasi-market benefits

Depending on the type involved, quasi-market benefits can be valued using different valuation techniques, based on cost-based or revealed preference methods (see Table 27). Quasi-market benefits enter the SNA through the production of the final market goods they contribute to. As such, they are implicitly recorded in the SNA. The valuation techniques described here only help to portion transactions so as to identify the contribution of forest ecosystem services. Accordingly, these methods are based on observed market transaction.

Valuing ecosystem services that are substitutable inputs into non-forest production

Ecosystem services that are substitutable inputs into non-forest production can be replaced by other human-produced services. Investment in these alternatives will only be made if the expected damage from losing the ecosystem service is greater that the replacement costs. Such ecosystem services can be valued based on two cost-based approaches.

- *Replacement cost method:* Ecosystem services can be valued through the observed expenditure for activities undertaken to compensate for a decline in the supply of a service. Examples include the costs of switching to alternative water sources or of water treatment when water quality in one source deteriorates, increased irrigation costs when water flows fluctuate, dredging costs to remove soil sedimentation, or the costs of building landslide protection mechanisms in areas prone to soil erosion.
- *Damage costs:* Alternatively, the same ecosystem services could be valued through the damages caused by their loss, such as the health impacts of deteriorated water quality, production losses due to water shortages, or landslide impacts due to soil erosion. Depending on the factors considered, these costs may not equate to an exchange value.

Valuing ecosystem services that are complementary inputs into non-forest production

Ecosystem services that represent complementary inputs cannot be (easily) replaced by other inputs. Losing these services can entail damage costs, but these can only be estimated through production function methods. These methods require an understanding of the relationship between different inputs in production. They link production data to ecosystem conditions that relate to an ecosystem service—for example, changes in pollination activity and coffee yields, soil retention and increased farm productivity, hydrological services and agricultural production, as well as hydropower generation through reduced soil sedimentation. Based on assumptions about the probability of finding a new species for pharmaceutical product development and the expected returns of a new product, the value of genetic material has been estimated.

Valuing ecosystem services that contribute to a heterogeneous market good

While some ecosystem services cannot be exchanged directly at markets due to their public good characteristics, they can form a unique attribute of another market good. For example, recreational services from forests can play a key role in tourism. Similarly, proximity to forest ecosystems with unique species can provide knowledge and information services that research facilities or educational institutions can benefit from.

Income flows related to forest-based tourism as well as research and education are recorded in the SNA through a number of related industries, such as hotels, accommodations, restaurants, and transport benefiting from national and international tourists and housing, retail, and transport benefiting from people working in forest-related research and education. The contribution of forests to these income flows may be singled out through entrance fees for national parks, hunting permits, or access rights to forest ecosystems. Where these payments are not required, however, special valuation techniques are needed.

- *The hedonic price method* has been widely applied to assess how environmental amenities affect property prices, mostly in urban contexts. For ecosystem services with spatial variation, this method can be applied to reveal the marginal price (or implicit price) of forest-related attributes (such as proximity to forests or the presence of unique animal or plant species). The advantage of these methods is that they present the value of an ecosystem service based on the market transactions for a standard market good. The drawback is that in most developing countries, the data available to apply this method will not provide a sufficient sample size.
- *In the travel cost method*, data collected from visitors to a specific forest site can reveal the value of the recreational services provided by that site through the travel costs and time incurred. As consumers would only be willing to accept this cost as long as the benefits from the recreational services provided are larger, travel costs can be interpreted as a marginal value for these services. This has several shortcomings, however. Travel costs only represent part of the full costs incurred. And more important, they only relate to the benefits experienced in one specific site (such as having access to a certain area of natural forests) and do not compare to other sites (such as having access to a larger area of natural forest somewhere else). Nevertheless, applying discrete choice models with data collected from different sites can help to explain how much consumers would be willing to pay to travel to a forest site with specific attributes.
- *Stated preference methods* have found wide application in the environmental economics literature to value recreational services in forest contexts through the willingness to pay for visits to forest reserves, including the contingent valuation approach in Costa Rica and Bolivia and choice experiments in Uganda. In order to derive values that are compatible with SNA estimates, stated preference needs to calculate marginal values. Such values can be calculated through a

special framing of the survey questions (such as willingness to pay to have access to one more hectare of a forest ecosystem), although this can bring design challenges, and marginal values for unconstrained goods are likely to be zero.

Valuing non-market benefits

Non-market benefits represent public goods (non-rival and non-excludable) that are not linked to any market good, such as the cultural heritage value for local forest dwellers in the Amazonian rain forest or the existence and/or altruist value for a consumer in Europe from knowing that this rain forest area exists and others take benefit from it.

The contribution of ecosystems to these benefits cannot be linked to any market goods and thus cannot be inferred from any market transactions. However, their economic values can be estimated through stated preference methods. These can return values for any ecosystem service based on the consumers' choices of different scenarios in hypothetical market contexts (such as choosing between paying a donation for preserving a unique forest ecosystem and no payment but degradation of that forest). Some studies have applied these methods to derive consumers' willingness to pay for the existence of forests with unique plants, animals, and/or landscapes in other places.

While these methods can be designed so as to calculate marginal values, for non-market benefits that represent unconstrained goods these would be zero. Furthermore, by definition non-use benefits cannot be linked to an exchange value concept.

6.6 Challenges

Although there are a growing number of valuation studies, many of these suffer from some general shortcomings.

- It is often difficult to quantify ecosystem services and the benefits from them, and the data availability in many developing countries is rather weak.
- The methods and underlying assumptions can vary, so monetary estimates are often not comparable.
- Many valuation studies do not follow the SNA principles, so values are not comparable to national accounts data.
- The distinction between the valuation of ecosystem services and benefits is not made clearly and hence application of values for accounting purposes is difficult.

In addition, all valuation methods have a number of methodological barriers to implementation.

- Direct market valuation methods rely on observable market data, which is often not available for ecosystem services.
- Revealed preference methods are built on detailed information about

individual behavior in real market context, and collecting sufficient quantities of such data to make the estimates representative may be difficult.

- Stated preference methods have been challenged for their hypothetical nature and their technical complexity.
- Benefit transfer methods depend very much on the number and quality of existing valuation studies undertaken in similar contexts.

Consequently, while designing existing valuation methods so that values are compatible with SNA is possible, it is likely to require the collection of new data. This bring with it the challenge of upscaling to a whole country estimates that were made for a number of study sites.

The following points highlight some specific aspects and challenges in measurement and interpretation.

- Marginal values (the value of small incremental changes in land use) are more meaningful in informing policy decisions than absolute values or average values, but they are also more difficult to compute.
- Valuation is challenging under non-linear relationships and threshold effects, which would require the consideration of large value changes for small changes in ecosystems.
- Monetary values depend on understanding where resources and ecosystem services originate and where they create benefit for humans, but often these spatial relationships are highly complex (the flow of water or sediments through space, for example).
- Estimates of NPV depend on assumptions about the future (which is highly unpredictable) and discount rates (which is often a political choice).
- Values are highly sensitive to fluctuating commodity prices and changing personal preferences.
- There is a risk of double counting when valuing different ecosystem services.
- Estimations using only exchange values will likely undervalue the contribution of forests to the economy from a social policy perspective; the same is true for the valuation of health and education in the national accounts—thus for different policy purposes, different valuation considerations and methods should be applied.
- Monetary valuation is based on the concept of weak sustainability, so monetary accounts will suggest that all natural capital could be replaced by human-made capital (but there are critical functions, tipping points, and irreversible changes).
- Putting values on forests may be politically contested (for example, regarding the commodification of nature).
- Monetary valuation ignores multiple dimensions of human well-being and the many ways that values are expressed.

Bibliography

Akerman, M., Peltola, T. (2012). *How does natural resource accounting become powerful in policymaking? A case study of changing calculative frames in local energy policy in Finland.* Ecological Economics 80:63–69.

Arias, M. E., Cochrane, T. A., Lawrence, K. S., Killeen, T. J., & Farrell, T. A. 2011. *Paying the forest for electricity: a modelling framework to market forest conservation as payment for ecosystem services benefiting hydropower generation.* Environmental Conservation 38(4): 473-484.

Australian Bureau of Statistics (2012). *Completing the Picture - Environmental Accounting in Practice.* Available in: http://www.ausstats.abs.gov.au/Ausstats/subscriber.nsf/0/2910B851D04B7DA2CA2579F900124AA9/$File/4628055001_may%202012.pdf

Center for Global Development (2016) *Why Forests? Why Now?* The Science, Economics, and Politics of Tropical Forests and Climate Change from the, http://www.cgdev.org/page/wfwn-paper-series

Chase, L.C., Lee, D.R., Schulze, W.D., Anderson, D.J., 1998. *Ecotourism demand and differential pricing of national park access in Costa Rica.* Land Economics 74 (4): 466–482.

Commission of the European Communities, International Monetary Fund, Organisation for Economic Co-operation and Development, United Nations and World Bank (1993). *System of National Accounts 1993*. Sales No. E.94.XVII.4. Available from http://unstats.un.org/unsd/nationalaccount/docs/1993sna.pdf.

Costello, C., Ward, M.B. (2006) Search, bioprospecting and biodiversity conservation. *Journal of Environmental Economics and Management* 52(3): 615-624

Day, B. (2013). *An overview of valuation techniques for ecosystem accounting.* Issue Paper 1.1, Valuation for Accounting Seminar. November 2013.

Economics and Statistics Department, *Government of Himachal Pradesh. (2010) Gross State Domestic Product of HP (1999-2000 to 2006-07)*

Ellingson, L., Seidl, A. 2007. *Comparative analysis of non-market valuation techniques for the Eduardo Avaroa Reserve, Bolivia.* Ecological Economics 60 (3): 517–25.

European Commission and Eurostat (2002). *The European Framework for Integrated Environmental and Economic Accounting for Forests: IEEAF*, 2002 ed. Luxembourg: Office for Official Publications of the European Communities. Available from http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-BE-02-003/EN/KS-BE-02-003-EN.PDF.

European Commission, International Monetary Fund, Organisation for Economic Cooperation and Development, United Nations and World Bank (2003). *Handbook of national accounting: integrated environmental and economic accounting 2003, Studies in Methods,* Series F, No. 61, Rev. 1. Available from http://unstats.un.org/unsd/envaccounting/seea2003.pdf.

European Commission, International Monetary Fund, Organization for Economic Cooperation and Development, United Nations and World Bank (2014) *System of Environmental-Economic Accounting 2012—Central Framework (SEEA Central Framework)*

European Commission, International Monetary Fund, Organization for Economic Cooperation and Development, United Nations and World Bank (2014) *System of Environmental-Economic Accounting 2012—Experimental Ecosystem Accounts (SEEA EEA).*

European Communities (2002). *Natural resource accounts for forests. Luxembourg: Office for Official Publications of the European Communities.* Available in: http://ec.europa.eu/eurostat/documents/3217494/5633257/KS-47-02-430-EN.PDF/145140dc-6a1d-4078-9db1-790a4701868f

Eurostat (2000). *Manual on the Economic Accounts for Agriculture and Forestry* EAA/EAF 97 (Rev 1.1). Luxembourg: Office for Official Publications of the European Communities. Available from http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-27-00-782/EN/KS-27-00-782-EN.PDF.

Food and Agriculture Organization of the United Nations (2010). *Global Forest Resources Assessment, 2010: Main Report*. FAO Forestry Paper No. 163. Rome. Available from http://www.fao.org/docrep/013/i1757e/i1757e.pdf.

Food and Agriculture Organization of the United Nations (2012). *Global Forest Resources Assessment 2010: specification of national reporting tables for FRA 2010.* Forest Resources Assessment Programme working paper No. 135. Rome. Available from http://www.fao.org/forestry/fra/67094/en/.

Godoy, R., Wilkie, D., Overman, H., Cuvas, A., Cubas, G., demmer, J., McSweeney, K., Brokaw, N. (2000). *Valuation of consumption and sale of forest goods from a Central American rain forest.* Nature 406, 62-63.

ICP-Forests in Europe and FHM (http://fhm.fs.fed.us) and FIA (http://fia.fs.fed.us) programs in the US gather various forest health indicators. One point of interest is the assessment of the effect of air pollutant.

INAB, CONAP, UVG, and URL. (2012). *Mapa de cobertura forestal de Guatemala 2010 y dinámica de la cobertura forestal 2006-2010.* Instituto Nacional de Bosques, Consejo Nacional de Áreas Protegidas, Universidad del Valle de Guatemala y Universidad Rafael Landívar. Guatemala; FAO. 2012 FAO forest resources assessment 2010. FAO forestry paper. Rome: FAO.

Intergovernmental Panel on Climate Change (IPCC) (2003). *Good Practice Guidance on Land Use, Land-Use Change and Forestry,* Jim Penman and others, eds. Hayama, Japan: Institute for Global Environmental Strategies for the IPCC. Available from http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_contents.html.

Klemick, H. 2011. *Shifting cultivation, forest fallow and externalities in ecosystem services: Evidence from the Eastern Amazon.* Journal ofEnvironmentalEconomicsandManagement61(2011)95–106

Millennium Ecosystem Assessment (2003). *Ecosystems and Human Well-being: A Framework for Assessment.* Washington, D.C.: Island Press. Available from pdf.wri.org/ecosystems_human_wellbeing.pdf.

Naidoo, R. and Adamowicz, W. L. 2005. *Economic benefits of biodiversity exceed costs of conservation at an African rainforest reserve. Proceedings of the National Academy of Sciences of the United States of America*, 102 (46): 16712-16716.

Pattanayak, S. K., Mercer, E.. 1998. *Valuing soil conservation benefits of agroforestry practices: Contour hedgerows in the eastern Visayas, Philippines.* Agricultural Economics 18 (1): 31–46.

Peters-Stanley, M., Hamilton, K., Yin, D., 2012. *Leveraging the Landscape State of the ForestCarbon Markets 2012.* Ecosystem Marketplace

Ricketts, T.H., Daily, G.C., Ehrlich, P.R., Michener, C.D. 2004. *Economic value of tropical forest to coffee production. Proceedings of the National Academy of Sciences of the United States of America* 101, 12579-12582.

Rolfe, J., Bennett, J., and Louviere, J. 2000. *Choice modelling and its potential application to tropical rainforest preservation.* Ecological Economics, 35 (2): 289-302.

Schaafsma, M., Morse-Jones, S., Posen, P., Swetnam, R.D., Balmford, A., Bateman, I.J., Burgess, N.D., Chamshama, S.A.O., Fisher, B., Green, R.E., Hepelwa, A.S., Hern+índez-Sirvent, A., Kajembe, G.C., Kulindwa, K., Lund, J.F., Mbwambo, L., Meilby, H., Ngaga, Y.M., Theilade, I., Treue, T., Vyamana, V.G., Turner, R.K. 2012. *Towards transferable functions for extraction of Non-timber Forest Products: A case study on charcoal production in Tanzania.* Ecological Economics 80, 48-62.

Simpson, R. D., Sedjo, R. A., and Reid, J. W. 1996. *Valuing Biodiversity for Use in Pharmaceutical Research.* Journal of Political Economy, 104 (1): 163-185.

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

FAO, *The FAO State of the Worlds Forests provides an extensive discussion and assessment of the broad socio-economic benefits of forests*, 2014

The World Bank. 2011. *Estimating the opportunity costs of REDD+. A training manual.* World Bank Institute, Washington DC.

UNFAO *Global Forest Resources Assessment* (FRA 2010) www.fao.org/forestry/fra/en/

United Nations and Food and Agriculture Organization of the United Nations (2004). *Handbook of national accounting: integrated environmental and economic accounting for forests.* Final draft.

Vardon et al (2016). *The accounting push and the policy pull.* Ecol. Econ, 124: 145-152

Vietnam Household Living Standards Survey (VHLSS) 2002 and 2004, Vietnam General Statistics Office; accessed via World Bank Living Standards Measurement Study website (http://iresearch.worldbank.org/lsms/lsmssurveyFinder.htm)

Woodland accounts: Khan, Greene & Hoo, (2013) Measuring UK Woodland Ecosystem Assets and Ecosystem Services, ONS; Timber resource accounts: Khan, Greene & Hoo, (2013) Monetary valuation of UK Timber Resources ONS.

World Bank Group's Forest Action Plan for FY2016-20

World Commission on Environment and Development (1987). *Our Common Future*. New York, Oxford: Oxford University Press.




WORLD BANK GROUP