WAVES

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Forest accounting sourcebook

Policy applications and basic compilation

DRAFT – For discussion only

WAVES

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

Global Partnership for Wealth Accounting and Valuation of Ecosystem Services (WAVES)

Wealth Accounting and Valuation of Ecosystem Services (WAVES) is a global partnership led by the World Bank that aims to promote sustainable development by mainstreaming natural capital in development planning and national economic accounting systems, based on the System of Environmental-Economic Accounting (SEEA). The WAVES global partnership (www.wavespartnership.org) brings together a broad coalition of governments, UN agencies, nongovernment organizations and academics for this purpose.

WAVES core implementing countries include developing countries – Botswana, Colombia, Costa Rica, Guatemala, Indonesia, Madagascar, the Philippines and Rwanda – all working to establish natural capital accounts. WAVES also partners with UN agencies – UNEP, UNDP, and the UN Statistical Commission – that are helping to implement natural capital accounting. WAVES is funded by a multi-donor trust fund and is overseen by a steering committee. WAVES donors include – Denmark, the European Commission, France, Germany, Japan, The Netherlands, Norway, Switzerland, and the United Kingdom.

Contents

1. Introduction

For many countries forests play a key role in 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 (the Sourcebook) responds to the 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 Sourcebook summarizes information on forest accounting that is found among other information, in particular the System of National Accounts (SNA) (EC et al. 2009) and the System of Environmental-Economic Accounting (SEEA) UN et al. 2014). The Sourcebook brings together the different material in these documents and makes the case for the relevance of forest accounts for 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 (e.g. input-output analysis and general equilibrium modeling). A feature of the Sourcebook is the link to examples and case studies that help to describe the practical steps for overcoming common measurement issues. In this way the Sourcebook helps to share knowledge and strengthen the global natural capital accounting community of practitioners.

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 for the Sourcebook include the broader research network of academics, non-government 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 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 of the Sourcebook are to:

- Raise awareness of the importance of forest accounting for policy planning and review
- Increase understanding of how forest accounts can help to address policy questions by describing and illustrating policy applications of forest accounts (including the use of indicators and modeling applications of the accounts)
- Provide guidelines for the compilation of forest accounts in line with the standard structures, concepts and classifications of the System of Environmental-Economic Accounting (SEEA)
- 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 show how remote sensing, spatial modeling, and statistical analysis can provide in-depth information and data to compile the accounts. An additional contribution of this document is to tackle aspects related to the measurement and valuation of forest ecosystem services. Over time, in conjunction with the Sourcebook, various presentations and training materials will be developed to assist countries in the implementation and application of forest accounts.

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 (ref). Forests cover 31% of the global land area (FAO, 2015), and more than 1.6 billion people around the world depend on forests for various daily functions (World Bank, 2002). Even though estimates of total economic contributions of forests vary widely, FAO estimates that formal forest industries contribute nearly 1% of global GDP yearly or more than $450 billion (FAO, 2012). In addition, more than 10 million people are formally employed by the forest sector (FAO, 2015). Although deforestation trends are declining globally, more than 13 million hectares of forests are being lost annually through conversion or natural losses (FAO, 2015). This issue combined 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.

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 1.1 introduces some of these initiatives including the UN Sustainable Development Goals, the strategic plans under the Convention on Biological Diversity, programs on Green Growth and Green Economy and the REDD initiative under the UN Framework Convention on Climate Change. Forest accounting can provide information support discussion and analysis in each of these initiatives.

Box 1.1 International initiatives relevant to forest accounting

UN Sustainable Development Goals

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

As the MDGs target date of 2015 is reached, the UN has just completed a new process for the creation of 17 Sustainable Development Goals (SDGs) covering all countries and with a heightened coverage of environmental factors. It was adopted by the UN General Assembly in September 2015. Forests are again important, especially in respect of Goal 15 "To protect, restore 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.

Convention on Biological Diversity (CBD)

Under the CBD, 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% of degraded lands by 2020 (Target 15). Further, 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.

UNDP Green economy and OECD Green growth initiatives

In recent years both UNDP and the OECD have developed initiatives aimed at supporting 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 our 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 forest land.

UN Reducing Emissions from Deforestation and Forest Degradation (REDD) programme

Since 1994, the United Nations Framework Convention on Climate Change (UNFCCC) has made key decisions and provisions for countries to mitigate climate change in the land-use, land-use change, and forestry sector (LULUCF). In this context, the UN programme on Reducing Emissions from Deforestation and Forest Degradation (UN-REDD) is a collaborative initiative designed to support developing countries to implement 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 and to the conservation of biodiversity.

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.

In addition, many initiatives both in the public and 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 (FLEGT) in the European Union and certification schemes like the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC).

Multiple responses and initiatives have been established to combat various forest-related issues. It is beyond the scope of this introduction to go into depth on any of these goals and targets, but from this short list one can see the complexities involved in addressing global forest challenges. For each of the aforementioned programs, an essential element is the measurement of forest resources. Through detailed and integrated statistics, forest accounts provide improved forest related information and indicators. Both the statistics and the associated indicators can 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; how to design economic policy instruments (e.g. property rights, taxes and subsidies, creation of markets for non-market forest services, etc.) (Lange, 2004); and provide the basis for monitoring policy implementation and effectiveness. In sum, forest accounts can help countries achieve various policy targets and meet the goals of any future initiative.

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. The data from the national accounts, including gross domestic product (GDP), are the primary data inputs for policy analysis and the data figure prominently 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/plantation forests the changes in stocks and production are accounted for in an integrated way. However, for natural forests, while the income generated through timber production is accounted for in GDP, any associated capital costs (i.e. depletion of natural capital) are not deducted from income. As a result, a country could deplete stocks of timber resources and raise GDP, but the costs of depletion would not be attributed.

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 and changes in stocks that permits an assessment of 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, has been expressed as "… development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (World Commission on Environment and Development, 1987).

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 in the national accounts. These extensions were integrated in the System of Environmental-Economic Accounting (SEEA), first released in 1993. (See Box 1.2) These satellite accounts are the forerunners of the forest accounts described in this Sourcebook.

Box 1.2 History of the SEEA

The potential and need to better integrate measures relating to natural capital within the national accounts framework emerged through the 1970s and 80s and led to the release of the first, interim SEEA in 1993. Over the past 20 years 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 incorporating 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 (SEEA EEA).

The SEEA Central Framework was adopted as an international statistical standard by the UN 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.

The SEEA EEA was endorsed by the UN 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.

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 (SEEA Agriculture) led by the 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 in all countries, forest ecosystems also provide non-marketed goods and services that contribute to livelihoods, but these are not usually recorded or identified in the national accounts. Relevant examples of these goods and services include watershed protection, carbon sequestration, and air filtration. 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. Currently, work is underway to finalize an application of the SEEA Central Framework, titled the SEEA for Agriculture, Forestry and Fisheries (SEEA Agriculture). For forestry, this will incorporate material on accounting for timber resources and forest land from the SEEA Central Framework and will add in accounting for forest product flows and inputs to forestry such as employment, capital machinery and energy costs.

To address the measurement of forests as ecosystems and the associated ecosystem services, the UNSC has endorsed a complementary volume, SEEA Experimental Ecosystem Accounting (SEEA EEA) (UN et al 2014b). SEEA EEA provides a framework for the integration of information on ecosystem extent, condition and capacity and information on ecosystem services, such that these data can be integrated with existing SEEA and SNA based information. The SEEA EEA has drawn inspiration from various non-statistical initiatives including the Millennium Ecosystem Assessment (2005) and the UNEP TEEB (The Economics of Ecosystems and Biodiversity) study (2010).

1.3 Structure of the Forest Accounting Sourcebook

The Sourcebook comprises two parts. Part I is aimed at potential users of forest accounts, including policy makers and analysts. Chapter 1 provides a short introduction, Chapter 2 provides a summary of forest accounting – its motivations, solutions and experiences in different countries. Chapter 3 focuses on applications of forest accounts to policy using country level examples to illustrate the potential use of accounts across a number of policy issues.

Part II is aimed at compilers of forest accounts. Chapter 4 describes the various types of accounts that are within 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 has a focus on concepts and methods in the valuation of forest stocks and flows. Examples and case studies are provided through these chapters to support understanding of the concepts and to give appropriate starting points for compilers of 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 that rely on and affect those resources. This is a tool that enables countries to make more informed decisions regarding the use of forest resources and to design and monitor policies that can help to achieve sustainable development.

2. A summary of national capital accounting for forests

2.1 The need for forest accounts

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

The objective in developing national level forest accounts is (i) to provide a framework in which these and other information on forests can be brought together to give a more complete picture of forests and (ii) to ensure that this information can be integrated within broader discussions on economic development and planning.

This second ambition 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 ambitions of sustainable development require 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 the added economic value of forests, largely recognised in timber production. While this information 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 re-growth in the timber stock could lead to unsustainable levels of timber 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 very close relationship between forests and people living nearby. The information on forests thus needs to encompass the variety of non-wood forest products that forests provide including food, energy, shelter and materials. The cultural connections between people and forests also need to be better understood and included in decisions about forest management.

Third, over the past 10-15 years an increasing body of research has focused on the description and measurement of a full range of ecosystem services. Beyond the more commonly identified goods that are harvested from forests (i.e. timber and non-wood forest products), the measurement of ecosystem services also recognises that forests play a generally unpriced role in supplying regulating services. 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 recognised as completely as possible, these regulating services should be accounted for.

This chapter provides a brief introduction to accounting for forests by providing an overview of the accounting solutions that have been developed in recent years and in describing the key aspects of accounting approaches. Part II of the forest source book provides a more complete description of the compilation of forest accounts and the relevant accounting methods and techniques.

2.2 Forest accounting solutions

One of the challenges in mainstreaming information on forests and other natural resources is that the most common metric for assessing overall economic activity, gross domestic product (GDP), does not take into account the costs of extracting natural resources in an unsustainable manner. This has long been recognized as a concern.

The solution that has been developed by the international statistical community, which also oversees the standards for measuring economic activity, is the System of Environmental-Economic Accounting (SEEA). Its focus is on organizing information such that the relationship between the economic 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 System of National Accounts (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 SEEA and SNA frameworks.

Accounting for timber resources and forest land

With respect to forests the SEEA Central Framework applies existing knowledge of natural resource accounting for timber and forest land into economic measurement and also draws heavily on the measurement and definitions developed in the context of the FAO Global Forest Resources Assessment (FRA).

The SEEA Central Framework 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 (e.g. due to storms or disease)
- Approaches to the valuation of the timber stock and the measurement of depletion
- Accounting for the area of forest land and changes in area of forest land 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 developed 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 non-wood forest products 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 it permits 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 example 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 the work on the development of the SEEA Central Framework when it was recognized that the traditional approaches to natural capital accounting were not sufficient to integrate information on the multiple and varied services of the environment and measures of the overall extent and condition of ecosystems.

The SEEA Experimental Ecosystem Accounting 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, etc.). For each ecosystem asset, the extent (area) and condition can be recorded following ecological measurement approaches that have been developed over many years. For example through 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 ecosystem asset supplies. These services are generally broken up into three types – provisioning services (e.g. of food, fibre, energy, water); regulating services (e.g. of water flows, climate, floods); and cultural services (e.g. recreation services and amenity). This break down builds on the work from the Millennium Ecosystem Assessment (2005), and the TEEB (The Economics of Ecosystems and Biodiversity) study (2010).

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 those ecosystem services that contribute directly to current economic measures of production (e.g. the contribution of pollination to agriculture) and those ecosystem services that represent additional production and consumption (e.g. the filtration of air by trees). SEEA EEA Chapter 2 provides a complete description of the ecosystem accounting model.

Accounting for ecosystem condition and ecosystem 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. Examples of nationally endorsed, ecosystem accounting work based on the SEEA EEA framework are present in Australia, Canada, Chile, Indonesia, the Netherlands, Peru, the Philippines, South Africa, and the United Kingdom.

<< Insert Box 2.1 on ecosystem accounting work in one country e.g. Philippines >>

2.3 The role of accounting

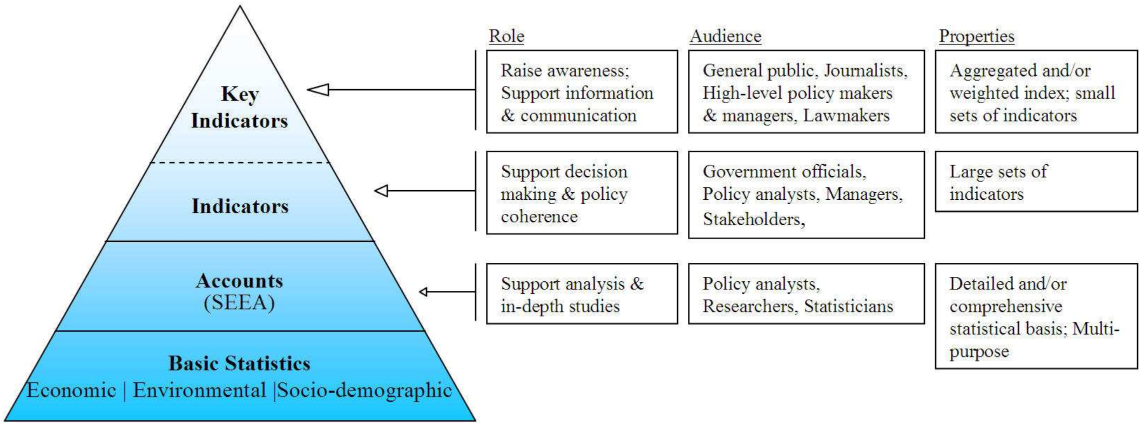
One of the challenges in making environmental information visible in economic and planning discussions is the lack of comparability and coherence between different environmental data sets, their, often incomplete, coverage and the lack of a clear link to existing economic data. In this context, the SEEA based accounting solutions described in the section above 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 example for industries and products). By way of example, the use of the SEEA framework requires that the biophysical information concerning forests (e.g. area, cubic metres of timber removed, etc.) aligns with the economic data (e.g. 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.

Third, accounting frameworks provide a summarizing role, bringing together much existing data. They therefore provide a complementary set of data rather than competing data. This logic is shown in Figure 2.1, 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 aggregate indicators on the other.

Figure 2.1 The information pyramid (from SEEA Applications and Extensions, Chapter 2)



Finally, SEEA based frameworks provide a platform for discussion and exchange between agencies and different disciplines. From a compilation perspective the compilation of environmental-economic accounts requires developing relationships between different data agencies. From a user perspective, the SEEA provide 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.

2.4 International experiences in natural capital accounting

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 the policy making process. 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).

Some particular examples serve to highlight the progress that is being made. First, there are a group of countries that helped to pioneer SEEA based accounting over the past 15-20 years. These countries include Australia, Canada, Denmark, France the Netherlands, Norway, Sweden and the UK. In each of these countries small teams were established and maintained over time. They each released a range of different SEEA accounts and 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.

Forest accounting at 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 UK. 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.

Work in an EU context

Building on the work of the pioneering SEEA countries, the EU through its statistical agency, Eurostat, has established piloting programs in many areas of natural capital accounting over the course of the past 15 years. Based on findings from these pilot programs, in recent years, the EU has passed a variety of regulations and directives related to natural capital accounting. For example, in 2011, the EU passed regulation No. 691/2011 that requires all Member States to compile data for three modules: air emission accounts, environmental taxes, and economy-wide material flow accounts,[1] and additional modules on energy flows, environmental protection expenditure and the environmental goods and services sector are also planned.

In relation to forest accounting, the EU 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 (IEEAF) 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 EU forest strategy was adopted in 2013. The strategy is focused on sustainable forest management, and providing true economic values for forest ecosystems. In addition, the strategy has objectives to realize forests' role in a green economy. [2] For all of the aforementioned directives and strategies, natural capital accounts can help to provide systematic information and data on key resources and ecosystems for informed policy decisions. Additionally the information garnered from accounts can help to generate useful indicators for monitoring and evaluation frameworks. Aligned with this the Eurostat reporting program on forest accounts is being reinvigorated (based on the work 15 years ago) with plans for an updated forest accounts questionnaire to commence in 2016 (tbc).

Increasingly, work on ecosystem accounting is being undertaken in broader contexts. For example, under the EU Biodiversity Strategy to 2020, action 5 calls for Member States to map and assess the state of ecosystems and their services, commonly referred to as MAES[3]. 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.

Global initiatives to implement natural capital accounting

The establishment of the WAVES program in 2010 has had considerable momentum to the implementation of natural capital accounting at national level. Significantly, the WAVES program has

[1] Full details on the regulation can be found here: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:192:0001:0016:EN:PDF
[2] A full report on the forest strategy can be found here: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0659:FIN:en:PDF
[3] For more information on MAES see: http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf

sought to move SEEA based measurement beyond the borders of the more statistically established countries of Europe and North America, and 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 been targeted to 8 countries at present – 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 (UNCEEA). (ref) In the context of this global strategy, various programs of SEEA implementation work are now being driven within the UN network of regional commissions such as UNESCAP, UNESCWA, UNECLAC, UNECA and UNECE. In addition, the FAO is starting to commence implementation support in the context of SEEA Agriculture, Forestry and Fisheries.

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 (e.g. Australia, Canada, Chile, 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.

Support for implementation

To support implementation and ensure appropriate guidance on specific topics a range of supporting documents have been developed. These include SEEA Water, SEEA Energy, SEEA Agriculture, Forestry and Fisheries, SEEA Applications and Extensions and the SEEA Implementation Guide. This sourcebook represents a further complement to these documents. There are also a range of training courses and other materials that can be accessed for other environmental themes (e.g. the International Recommendations on Water Statistics).

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 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/).

3. Applications of forest accounting

3.1 Introduction

The usefulness of forest accounts ultimately lies in the ability to use the information to inform decision-making at sector or national level. The compilation of forest accounts as described in this Sourcebook simply provides a tool 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 of the applications relate to a single forest accounting framework – i.e. 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: (i) policy monitoring and indicators; (ii) macroeconomic and forestry sector analysis; and (iii) integrated development and land use planning, including assessment of ecosystem services and biodiversity. There are necessarily overlaps between these areas driven by the multifaceted role that forests play in our societies and economies. However, the different groupings help to provide some sense of the variety of means in which forest accounts can be used. The examples of applications provided here should not be considered fixed. It is likely that other uses and applications will be found over time as the information set becomes known and develops over time.

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 problem or issues that certain countries are facing and develop a range of relevant policy questions that help to frame the issue in a way that clarifies the information requirements.

Many of the policy uses will relate to the management of resources or developing cross-sectoral policies. In this context the following policy questions emerge (Lange, 2004 and Lange, 2003):

1. What is the total economic contribution of forests and forest ecosystems and what are the benefits from sustainable management?
2. What is the distribution of benefits from forests among different groups in society?
3. Is economic growth sustainable or is it based on the depletion of forests?
4. What are the trade-offs among competing users and how can resource utilization be optimized?
5. What are the impacts of other sectors' policies on forests?
6. Is the maximum rent being generated and recovered by forest management policies; if not, are there other socio-economic 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 3.1. 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 through the development of forest accounts.

Table 3.1 Selected policy applications of forest accounts

Indicator/measure	Use for policy analysis	Examples of policies and actions taken from policy analysis
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.
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/compensation of local communities - negotiate international payments for carbon storage services of forests. Build multi-sectoral stakeholder alliances on the basis of mutual benefits. Identify institutional weaknesses in forest management, e.g. where one sector benefits but does not pay, or does not have a say in forest management.
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 PRSPs.
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, e.g. benefits to subsistence users/local communities are low because commercial/downstream users obtain 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.

Indicator/measure	Use for policy analysis	Examples of policies and actions taken from policy analysis
		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.
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.
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. Identify the economic trade-offs among competing sectors.	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. Identify winners and losers. Design appropriate economic instruments to achieve that strategy (fees, compensating payments, property rights, etc.).
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. Identifies potential conflicts between development objectives of forestry and those of other sectors, e.g. commercial logging vs catchment protection (Ministry of Agriculture, Ministry of Energy, etc.). Identify conflicts among divisions of the same ministry (Ministry of Agriculture), e.g. pastoralists' use of forest vs downstream crop farmers.	Identify winners and losers. Identify optimal forest management strategy, based on addressing conflicts among ministries and within a single ministry. Design appropriate economic instruments to achieve that strategy (fees, compensating payments, property rights, etc.).

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. We 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 of 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 there are an increasing number of reporting requirements related to forest information. From a country level perspective it would be beneficial if the relevant information could be co-ordinated 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 accounts framework include:

- Five yearly reporting to the FAO as part of the Global Forest Resources Assessment
- Regular reporting on the UN SDGs, in particular Goal 14 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 UNFCCC, particularly those related to land use, land use change and forestry (LULUCF).

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 estimates of comprehensive wealth and genuine savings and the UNDP/IHDP inclusive wealth estimates. The development of these types of measures at 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 national level, the development of a set of forest accounts would direct support the preparation of State of Environment reports which 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 Gundimeda et al, 2007).

<<Insert Box 3.1 summarizing Gundimeda et al. >>

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 seen 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 do not provide for 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 the direct economic related questions relevant to forestry. Table 3.1 provides some example of relevant policy questions that can be tackled using forest accounts. Forest accounts, especially ecosystem based accounts, can identify potential conflicts, at both a national level of 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 assist in the building of multidisciplinary relationships across ministries and among different stakeholders in the private sector, as they realize the extent of their dependence on forests.

Investigating these questions using a standard set of forest accounts that can be integrated with information for 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 defined in a way that facilitates the integration of information.

An example that highlights this aspect of accounting is presented in Box 3.2. Here, the use of forest accounts to understand the dynamics of illegal logging in Guatemala is explained. 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 3.2: Guatemalan application of forest accounts

Guatemala is a small, culturally-rich Central American country that houses 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 capital accounting is a tool that can provide data to inform the policy discussion surrounding natural assets. Increasing deforestation rates are a concern globally.

Guatemala has lost a total of 106 hectares of forest cover per day between 2006 and 2010.[4] This is equivalent to an annual deforestation rate of 1.4%, and to provide context, the deforestation rate for all of South America is 0.47%.[5] 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. The reason for the misunderstanding is due to calculations based on dated statistics and studies. As a result, the extent of illegal logging has been underestimated.

[4] INAB, CONAP, UVG, and URL. *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.

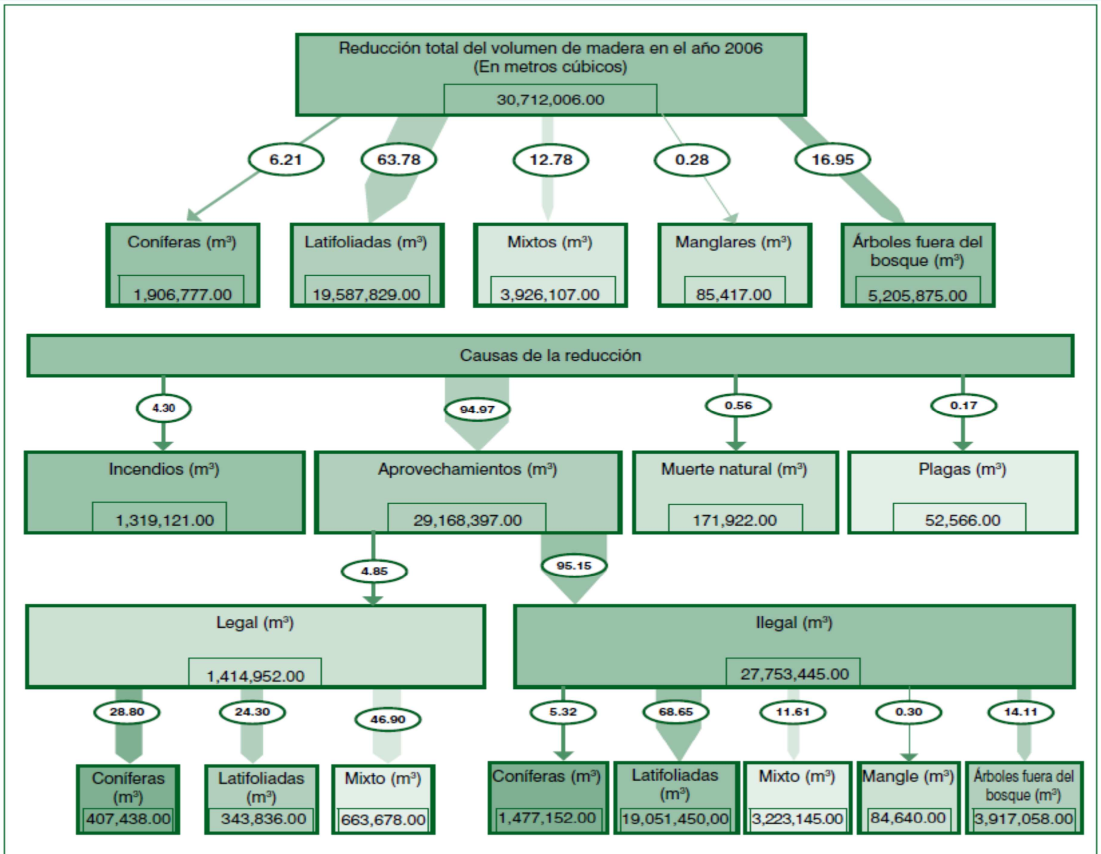
[5] FAO. 2012 FAO forest resources assessment 2010. FAO forestry paper. Rome: FAO.

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 the values for forest products are being more accurately valued. From the accounts, it became evident that illegal logging was more of a problem than previously thought. In fact, more than 96% of the timber extracted from Guatemalan forests came from illegal extractions (Figure 1).

The accounts also illustrated that illegal logging stems from two sectors of society: (i) households and (ii) 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 at greater distances 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 more fully understood 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 of 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



Fuente: Elaboración propia con base en BANGUAT y URL, IARNA, 2009.

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 appropriately present information 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 to 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.

A number of examples of the potential for the application of forest accounts to policy in six WAVES countries are presented in Box 3.3. They highlight the potential breadth of the integration challenges with dimensions around forests including: tourism, watershed management and protection, distribution of resources, coastal protection, green growth and climate change.

Box 3.3 Policy applications of forest accounts in WAVES countries

By determining essential benefits that forests provide, **Madagascar** can make informed decisions about how to finance its protected area network that covers 6.9 million hectares and houses unrivaled biodiversity. The potential economic benefits from tourism and watershed protection across the network are estimated at $48 million per year; however, only $0.5 million per year (ref) 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.

One of the greatest sources of wealth that **Colombia** can offer to the global market is the country's incredible biodiversity. To protect these resources and ensure that the distribution of resources is equitable, accounts that value ecosystem services, especially those that flow from forests, are necessary. By quantifying forest assets and constructing a supply-utilization matrix for each watershed, the country can reduce uncertainty about data on supply and demand of timber resources. From this information, Colombia will be prepared to design policy mechanisms to incentivize sustainable forest management.

Only 19% of the land in the **Philippines** remains forested. To provide policy applications that will help to manage competing land uses, develop sustainable forest industries, and increase benefits to local communities, the Philippines needs tools that calculate values for all forest services. Specifically, forest accounts are being developed for mangroves to provide important information about 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.

With ambitious goals associated with green growth, **Costa Rica** 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 can be conscious of the vast array of services that forests provide when designing development plans. The forest accounts are being compiled to ensure that Costa Rica has better analytical and decision-making tools to inform policy decisions on sustainable forest management, including the 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 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 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 of the clear messages 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 those making decisions have as complete and coherent set of information as possible. The example from Andalucia is relevant in this regard (Box 3.4).

Box 3.4 Policy example from Andalucía, Spain

The government for the region of Andalucia, Spain is financing a study to examine various government subsidies and if they have contributed 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 the hope 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 possibilities of this type.

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

In Box 3.5, forest accounts are shown to provide the data to underpin the development of macro-economic models – in this case an input-output model for the Scottish forestry industry.

<<Insert Box 3.5 - Example of Scottish analysis>>

In relation to the ecosystem services provided by forests, a variety of models can help to identify the value of ecosystems and analyze tradeoffs of different development schemes. For example, the InVEST Model, developed by The Natural Capital Project, combines the ecological production functions with economic valuation approaches including market valuation, avoided costs, and production economics. This tool is free to use, scientifically viable, and has many features that allow for flexibility. InVEST is spatially explicit, focuses on the ecosystem services, details the relationships among multiple resources, and is scenario driven. [6] This model relies on existing knowledge, but is modular and allows users to deal flexibly with data availability and changing knowledge.

[6] For more detailed information see: http://www.naturalcapitalproject.org/InVEST.html

Another tool, developed jointly by the Natural Capital Project and The Nature Conservancy, RIOS can allow for 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 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.

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 (Lange, 2004) 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 a country are assessed or estimated using the same standard concepts and definitions. Therefore, 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. Its activity is defined by 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, such as air filtration services, carbon sequestration services and recreational opportunities. These goods and services have no established market price, despite their significant contribution to human wellbeing. The ecological and social significance of forest resources and their utilization also have considerable effects on other parts of the economy and public welfare, and are of great political concern (Sekot, 2007).

Vincent (1999) 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 (Lange, 2004). Thus, not only are the total benefits from sustainable forestry underestimated, but other economic activities are not aware of their dependence on healthy forests (Lange, 2004).

These 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 is important in underpinning improved management decisions, and environmental and economic policy development (Kriström and Skånberg, 2001).

As Lange (2004) points out, establishing a forest accounting framework paves the way for establishing a value closest to the true socio-economic 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 the 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 (e.g., local community preservation, increased equity).

Forest accounts provide detailed statistics that may be used in economy-wide models to assess the impacts of 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.

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 Central Framework can be considered to reflect a resource-based approach to measurement while the SEEA EEA presents an ecosystem-based approach - see Box 4.1

Box 4.1: 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 the measurement of the changes in condition and extent of the stock of ecosystem "assets"; and the measurement of the ecosystem services that flow from those assets.

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 seen as 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[7]

In the SEEA Central Framework, physical flow accounts record the flows of materials and energy (i) from the environment to the economy (natural inputs); (ii) within the economy (products); and (iii) between the economy and the environment (residuals). Physical flows are recorded in physical supply and use tables. These tables are extensions of the monetary supply and use tables used in the SNA for the recording of flows of products in monetary terms. To align the physical and monetary tables, the ISIC classification for industries and the CPC classification for products are used. Generally,

[7] 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.

physical flow accounts are designed to record flows relating to a single type of material or energy, such as water, GHG emissions and energy, and hence a single unit of measure (tonnes, 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.

Asset accounts[8]

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

Economic activity and transactions related to the environment[9]

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, i.e. 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 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 activity. 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 flows 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 pest and disease. To some extent these flows will be reflected in reduced flows of some ecosystem services (e.g. lower flows of provisioning services) (SEEA EEA 2.24).

[8] Further detail on asset accounts is provided in the SEEA Central Framework Chapter 5 and the SEEA EEA Chapter 4.

[9] Further detail on accounts related to environmental transactions is provided in the SEEA Central Framework Chapter 4.

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 Central Framework, 5.1). Thus, environmental assets are defined broadly in the SEEA Central Framework 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 Central Framework, 2.17). The term "environmental asset" has been defined to acknowledge the value inherent in the components that comprise 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, as described in the SEEA Central Framework, reflects the more traditional measurement approach in which forests are considered in terms of two primary environmental assets: forest land and timber resources.

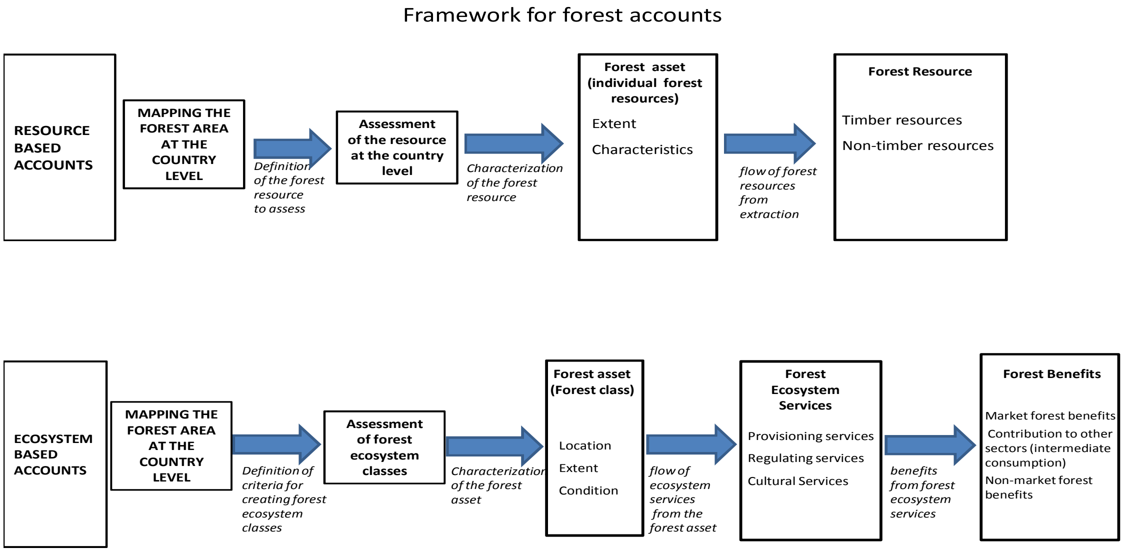
The ecosystem-based perspective, described in the SEEA EEA, considers forests as systems, acknowledging their role in providing a multiplicity of services that benefit society. The focus of the ecosystem-based approach is the measurement of ecosystem assets. Ecosystem assets are defined in terms of spatial areas of similar type – for example, forests, grasslands, 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 4.1. 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 Central Framework and the related ecosystem extent accounts described in the SEEA EEA.

The FAO provides an international classification of forests and criteria to distinguish classes of forest land. Box 4.2 presents this classification. Although countries are encouraged to follow the FAO definitions, in many cases they have developed their own definitions of forests.

Figure 4.1 Pathways in compiling forest accounts



Resource-based accounts for forests

The resource-based approach encompasses accounting for forest land and the individual resources that are obtained from forests. Typically, accounting for forest land 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 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 which will account for all land in a country – i.e. including forests, grassland, wetlands, agricultural and urban areas, etc. This account will form the basis for accounting for forest land and for defining the resources to be assessed within the forest area. Considering timber as an example, in areas identified as forests, timber resources should be measured according to the main relevant characteristics, e.g. broadleaved and conifer species, age classes and according to the main accounting classes (e.g. cultivated and natural classes) in the appropriate physical units for this resource (generally cubic metres for timber). 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 (e.g. in orchards) 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. For this purpose, using spatial areas as the units of analysis is most appropriate. As for 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 creating homogeneous forest ecosystem units (EU) (for example, based on vegetation type). According to these criteria, the forest

EU will be classified into different forest classes. These forest EU will be the ecosystem assets which 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 finally, their 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 EU in terms of species composition, structure and key ecological processes. Example indicators include measures of tree density, canopy cover and species diversity and 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.

Box 4.2: Forest land classification in FAO FRA2010

The FAO Forest Resource Assessment 2010 for forestland distinguishes among the following forest land classes:

Forest land is defined as: **land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ***. Forest land is classified according to different types of forest. The primary distinction is between naturally regenerated forest and planted forest.

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% of the growing stock at maturity**.

Two broad types of naturally regenerated forest are distinguished:

i. **Primary forest** is naturally regenerated forest of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed. Key characteristics of primary forests are that (a) they show natural forest dynamics, such as natural tree species composition, occurrence of dead wood, natural age structure and natural regeneration processes; (b) the area is large enough to maintain its natural characteristics; and (c) 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.

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

Planted forests are predominantly composed of trees established through planting and/or deliberate seeding. Planted/seeded trees are expected to constitute more than 50% of the growing stock at maturity, including coppice from trees that were originally planted or seeded.

Other wooded land is land not classified as forest land, spanning more than 0.5 hectares; with trees higher than 5 metres and a canopy cover of 5-10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10%. 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 to compile accounts based on the total area of different tree species.

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

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

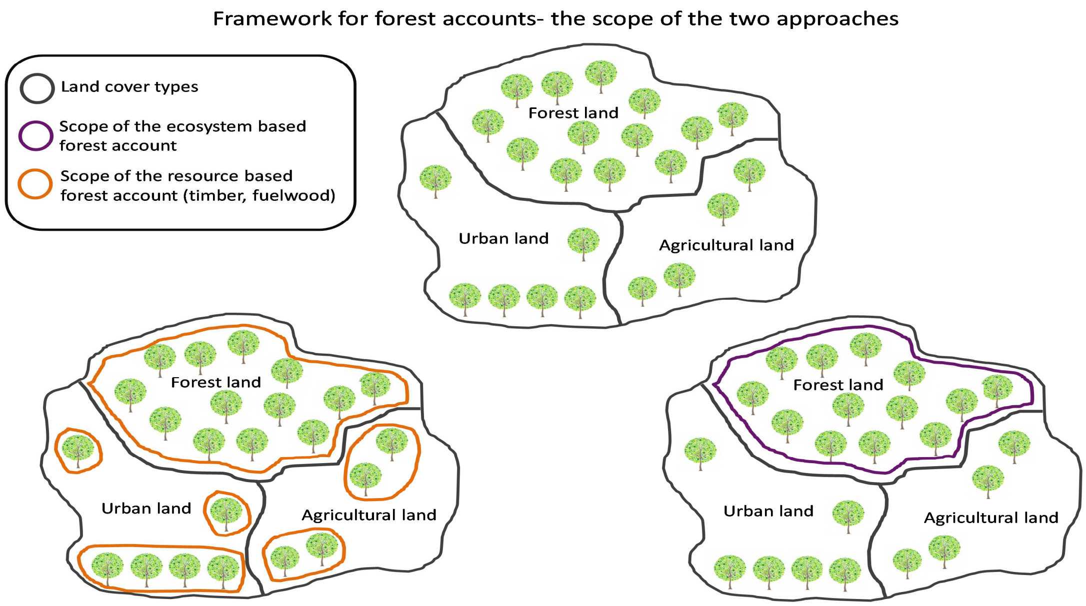
The two approaches are related as they both start from measurement of the forest area in a country and they both assess forests following an accounting logic. However, while the ecosystem-based accounting focuses on forest ecosystems in terms of spatial areas, the resource-based approach focuses on individual 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 as reflecting the main provisioning services provided by forests. Most likely these will flow to the society as benefits traded in markets. Further, measuring changes in the stock of timber resources and the area of forest land via resource-based asset accounts is likely to provide some 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 4.2. The key points are that

- Land accounts will use as their starting point all types of land – forest, urban, agricultural, etc.
- Accounts for forest land 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.
- In a resource based account for timber resources it is possible to include tree-related resources that are outside forest land, such as timber provided by trees in orchards or agro-forestry systems. Such information may be useful for some policy purposes such as the measurement of carbon sequestration and assessing sources of energy.

Figure 4.2 Scope of the forest accounts in this Sourcebook



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 behaviours 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 forest ecosystems.

Groupings of institutional units that undertake similar types of productive activity are referred to as industries. In forest accounts the key industry is the forestry industry which will encompass 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 of relevance 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 the forest ecosystems and resources is of particular interest to make 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 that are resident within the geographic boundary (or economic territory) of a country. By convention, all land, including forest land, is considered to be owned by a resident economic unit. If a foreign economic unit, i.e. it is based in another economic territory, owns land then it is considered to be purely a financial relationship and 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. The measurement of flows centres on three economic activities: production, consumption and accumulation. Among these, the production boundary is the most significant measurement boundary. All products (goods and services) that are regarded as produced through a combination of labour 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 gross domestic product (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 natural resource by economic units occurring at a level greater than that of regeneration (see SEEA Central Framework 5.76 and section 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 (e.g 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 ecosystem asset to provide a basket of ecosystem services in a sustainable manner. Attributing the declines in condition that are due 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 and 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

Scope of the accounts

In the resource-based accounts of forests, the different forest resources are accounted for individually, resource by resource. Traditionally, timber and forest land are the two environmental assets considered. In recent years, forest accounts are also beginning to consider recording 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 forest land, 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. However, in monetary terms 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 the 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 Central Framework 5.24). The treatment is explained in Box 4.3.

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 over-exploitation is recorded as part of GDP, but the corresponding depletion of the forest stocks would not be recorded as a cost against income (Lange, 2004). 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 4.3 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 (e.g. 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 management 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 (i) control of regeneration (seeding, planting of saplings); and (ii) regular supervision of the trees to remove weeds, attend to pests. It should be the case that the process of production is one that is classified to forestry activity following ISIC Division B.

Control over the 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 these above mentioned criteria. 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

Forest land 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 (i.e. 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. However, sometimes, the 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. Forest land accounts and timber resource asset accounts have a different focus but are related since, in most countries, the majority of timber resources in most countries 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 (e.g. 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 4.1) which are also included in the SEEA Central Framework.

Table 4.1 presents a physical asset account for forest and other wooded land. It shows the opening and closing stock by area and by type of forest, and the changes in the stock. Countries can further divide the forest land classes to distinguish details that are of relevance to the country (such as conifer/broadleaved/mixed forest land).

There are different additions and reductions in stock that should be recorded following the SEEA Central Framework (para 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 as a result of 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 4.1. 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 over the accounting period. A basic structure of a physical asset account for timber resources is presented in Table 4.2.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 4.2 timber resources are initially classified as either cultivated or natural (see Box 4.2 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 understand 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 provided by the FAO Global Forest Resources Assessment 2010 (FRA2010). **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 Central Framework 5.350) If a different definition is used at 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, those resources that are found in areas not classified as forest land such as orchards or along roadsides.

Table 4.2 The physical asset account for timber resource (cubic metres 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, i.e. 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 of 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 (for example, 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 the removal 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 (i.e. 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.

The monetary resource-based asset accounts

Forest land 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 the 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, land used for maintenance and restoration of environmental functions, and land 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 IUCN (see Box 4.4). This land should be classified in the category "Land used for maintenance and restoration of environmental functions". Finally, land where there are 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 which do not supply identified goods or services, i.e. 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 4.4 SEEA Central Framework Land use classification – Land use for maintenance and restoration of environmental functions

This class includes protected areas as defined by IUCN, International Union for Conservation of Nature, i.e., 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

(Source: SEEA Central Framework appendix 1.B, §1.5)

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

Table 4.3 shows the monetary asset accounts for land. The cells in grey show the classes where forest land is most likely to be recorded. The opening value of the stock of forest land corresponds to the sum of the values of the forest land (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 accessibility of the land as well as physical and regulatory constraints on their uses.

Most physical changes in forest land 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 the closing of the accounting period that are due solely to changes in price.

Table 4.3 Monetary asset accounts for land *(currency units)*

	Type of land use							
	Agriculture	**Forestry**	Land used for aquaculture	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, Table 4.4, follows the same structure as the physical asset account for timber resources. However, timber not available for wood supply is not included in the monetary asset 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 net present values 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 impact on the net present value 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, i.e. before extraction.

Catastrophic losses require a particular treatment since the resource might be only partly impacted. 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 not only related to physical fluxes of timber resources, but also to changes in 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 4.4 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 (e.g. timber, NTFP) or measured in terms of natural inputs of energy (i.e. fuelwood) – see for example SEEA Central Framework Table 3.5. The resource-based flow accounts are aligned with the production boundary of the SNA.

Supply and use tables (SUT), Table 4.5 show 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 (households, government, capital formation and exports). From these tables, commodity balances for forest products may be constructed, as well as input-output (IO) tables and social accounting matrices (SAM) in which the production of forest products is represented in physical terms (Lange 2004). Such tables can be expanded to include other forest resources.

Table 4.5 Physical supply and use tables for wood products

Table 6.9: Physical supply and use table for wood products, France, 1999
(timber, logs and wood in 1000 cubic metres; pulp, paper and waste in 1000 tons)

SUPPLY	Output by industry									
	Forestry & logging	Wood products	Pulp	Paper	Printing	Recycling	Other	Total ind. supply	Imports	Total supply
Standing timber	95920							95920		95920
Sawn logs	23162							23162	1451	24613
Firewood	31200							31200	27	31227
Pulpwood	11869							11869	699	12568
Wood and wood products		13017						13017	3490	16507
Paper pulp			2591					2591	2212	4803
Paper				9602				9602	5612	15214
Wood waste as product		8152						8152	686	8838
Paper waste as product					5066			5066	1238	6304
Non-timber forest products							X	X		X
Forest Services							X	X		X

USE	Intermediate consumption by industries								Final users			Total use
	Forestry & logging	Wood products	Pulp	Paper	Printing	Recycling	Other	Total int.	Consump-tion	Capital formation	Exports	
Standing timber	66232							66232		29688		95920
Sawn logs		23337						23337			1276	24613
Firewood							2423	2423	28429		375	31227
Pulpwood			10944					10944			1624	12568
Wood and wood products		7736					6076	13812			2695	16507
Pulp				4372				4372			431	4803
Paper							4465	4465			4167	8632
Wood waste as product		2265	2162				3431	7858			980	8838
Paper waste as product				5276				5276			1028	6304
Non-timber forest products												
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 4.6, which presents a stylised 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 – either in the form of inventories or in the form of fixed assets.

Table 4.6 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 Value added	Household final consumption expenditure	Government final consumption expenditure	Gross capital formation (incl. changes in inventories)	Exports	Total use

Note: dark grey cells are null by definition

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 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 10m2 and 100m2). Each BSU will have some particular characteristics including slope, altitude, vegetation, etc.

Groupings of similar, contiguous BSU form an Ecosystem Unit (EU)[10]. 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 EU 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[11] which are relatively large areas about which there is an interest in recording, understanding and managing changes over time. Geographical aggregations should take into account administrative boundaries, environmental management areas, large scale natural features (e.g. river basins), and other relevant factors (e.g. protected areas). Defining geographical

[10] In the SEEA EEA, EU had been termed Land Cover/Ecosystem Functional Units (LCEU)
[11] In the SEEA EEA, geographical aggregations had been labeled Ecosystem Accounting Units (EAU).

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 EU 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 the country as a whole. Note that, as appropriate, forest EUs can be aggregated to obtain, for example, the total area of forests.

The 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:

1. Ecosystem extent, mainly related to the area and location of ecosystems
2. 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 forest land. 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:

i) A description of ecosystem assets in terms of relevant characteristics

ii) 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 taking into consideration its use.

Assessing changes in ecosystem assets: degradation, conversion and enhancement

Three major changes can take place related to ecosystem assets: degradation, conversions 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 (e.g. 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 and beyond activities that may simply maintain an ecosystem asset.

The 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 a national level it is likely to be of interest to compile an ecosystem extent account which 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 4.7.

The types of EU shown in Table 4.7 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 forest land physical asset account.

Table 4.7 Ecosystem extent account *('000 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 bodies	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															
Reductions in stock															
Managed regression															
Natural regression															
Downward reappraisals															
Net change in stock															
Closing stock															

Ecosystem condition accounts may be structured following Table 4.8. 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 a 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 4.8 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 ecosystem 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 activity. The flow accounts in the ecosystem-based 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 ecosystem services are considered:

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

ii. *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.

iii. *Cultural services* are generated from the physical settings, locations, or situations which 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 to which they contribute. The ecosystem-based approach enables users to identify a spectrum of benefits, ranging from the market benefits, the quasi-market benefits, and the non-market benefits. Ecosystem services contribute to the generation of all of these types of benefits.

Physical accounts for ecosystem services

The physical accounts of ecosystem services organizes 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, which will reflect the relevant physical properties of the underlying input such as tonnes or cubic metres 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 tonnes of carbon sequestered.
- Cultural services are likely to be measured in units related to the people interacting with the ecosystem and using the ecosystem service (e.g. number of people visiting a site or the time spent using the service).

Chapter 5 of this sourcebook shows examples of suitable indicators for the measurement of the ecosystem services provided by forest ecosystems. Annex 4.1 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 ecosystem 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 4.9 Physical flow of the supply of ecosystem services for different forest EU

	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. tonnes of timber			
Regulating services	e.g. tonnes 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. However, because the ecosystem approach is area-based, 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 4.10 illustrates how these transactions can be reflected.

Table 4.10 Supply and use of ecosystem services for a geographical aggregation

	Supply of ecosystem services					Use of ecosystem services				
	Enterprises	Households	Government	Rest of the world	Total	Enterprises	Households	Government	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 generally, ecosystem services and ecosystem assets are 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 values of marketed goods and services. These aspects are further developed in the Chapter 6 of this sourcebook.

One way of bringing this information together is to create combined 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 ecosystem 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 activity that take place outside the market and/or is not recorded in the standard economic measures of production, consumption, income and wealth. Chapter 6 of this sourcebook provides a description of approaches for the valuation of ecosystem services and ecosystem assets.

The ecosystem monetary asset account

The ecosystem monetary asset account follows 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 4.11. Since the estimates are compiled in monetary terms, in theory, estimates for different ecosystem assets can 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 4.11 Monetary ecosystem asset account

	EU type	Total area
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

These accounts present transactions in monetary terms that are already recorded in the SNA but that cannot be easily identified due to the structure of the accounts. The types of transactions recorded in these accounts are:

- Transactions concerning activities undertaken to protect the environment that also can include resource management activities
- Transactions such as taxes and subsidies that reflect efforts by governments to influence behavior of producers and consumers with respect to the environment.

This information can be used to help assess whether economic resources are being used effectively to reduce pressures on the environment and to also allow for different policies to be compared and contrasted.

Environmental activities: scope and definition

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

1. Environmental protection activities are those activities whose primary purpose 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 towards environmental protection.
2. Resource management activities are those activities whose primary purpose 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, these activities may be of particular interest in the assessment of environmental impacts and the development of environmental policy. The two activities are

1. Natural resource use activities involve the extraction, harvesting, and abstraction of natural resources and activities.
2. Activities associated with the minimization of the impact of natural hazards on the economy and society. Activities such as provisioning for fighting the effects of forest fires would be recorded in this section.

Environmental activity accounts and statistics

Two different sets of information can be compiled to provide information on environmental activities:

- Environmental Protection Expenditure Account (EPEA)
- Statistics on the Environmental Goods and Services Sector (EGSS)

The EPEA follows the accounting principles of the SNA. It is composed of 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 EPEA, would comprise 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 approaches 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 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 for compilers. 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 clearly defining the scope of resource management activities in order to establish a resource management account for forests.

Longer term, the objective should be to develop a standard base of information on forest land, 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 (i.e. primarily timber resources from forests), a longer term objective should be valuing other forest ecosystem services in monetary units 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 recognised that defining the depletion of forest related resources is not straightforward and 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 activity and those aspects of ecosystems that, effectively, support the provision of these benefits. For national accountants it requires broadening the production boundary and considering alternative approaches to valuation. Engaging in the discussion of these topics between these and other disciplines will be essential to making progress in this area.

Annex 4.1 Measurement approaches for ecosystem services

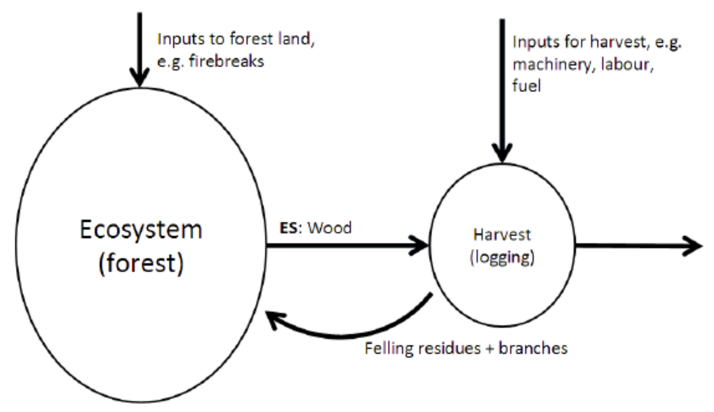
Measurement approaches for provisioning services

Provisioning services: provision of wood and non-timber forest products

A forest ecosystem from which wood and non-timber forest products are obtained is shown.

For logging or for extraction other forest products, such as cork or berries, a number of inputs are required (e.g. labour, machinery, 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.

Figure A3.3 Provisioning of wood as a natural biological resource



Measurement approaches for regulating services

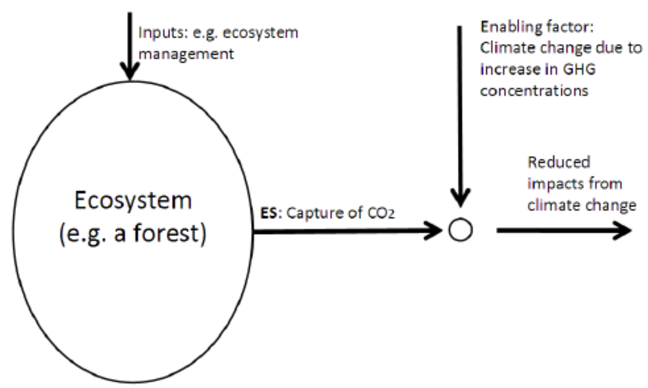
Regulating services: sequestering of carbon and carbon storage

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

1. 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 due to accumulation in below ground carbon reservoirs.
2. The ecosystem service of carbon storage is the avoided flow of carbon resulting from maintaining the stock of above ground and below ground 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 (e.g. fire), or other factors.

The conceptual model of the ecosystem service as a function of ecosystem state and enabling factors is presented. Enabling factors is the term used to describe the context without which the ecosystem service would not be delivered. In this case, the service of carbon sequestration arises due to the presence of climate change and the increase in GHG emissions. Ecosystem management will generally affect the net sequestration and/or the storage of carbon in the soil.

Figure A3.4 Sequestering of carbon

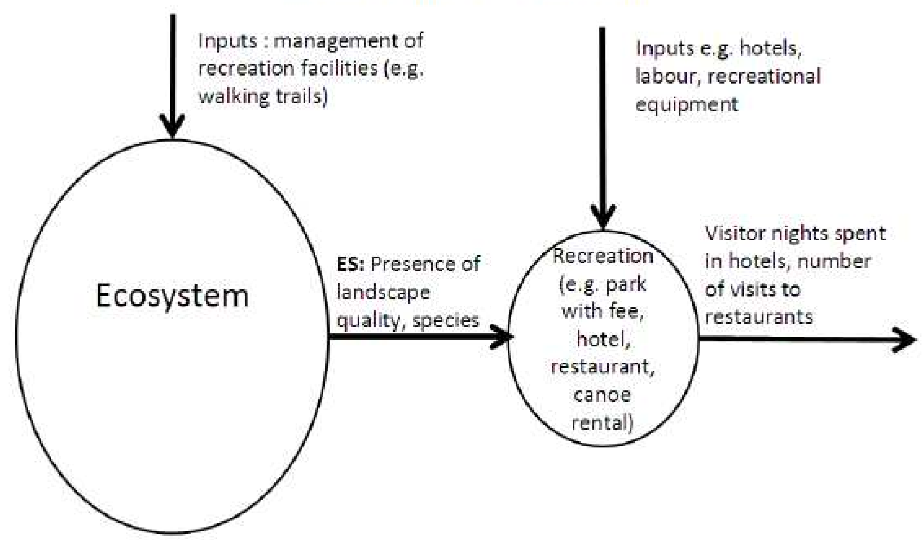


Measurement approaches for cultural services

Cultural services: tourism and recreation

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. As in the case of provisioning services, the use of ecosystem services in tourism requires that a specific activity be undertaken (i.e. the recreation activities by people in an ecosystem).

Figure A3.7 Tourism and recreation services



5. Compiling physical accounts for forests

5.1 Background

The structure of the physical accounts for forests was 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 describing general indicators of forest stocks and flows, and proposing 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.

This chapter is divided into three main sections. Section 5.2 presents an overview of possible data sources for the compilation of physical forest accounts. Sections 5.3 and 5.4 propose a series of generic indicators to be taken as pathways to compile the asset and flow accounts. In addition, ways to process the data are described with the goal of populating the accounting core tables. Section 5.5 briefly outlines some measurement challenges.

5.2 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 the means by which these various data sources can be integrated.

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:

1. Forest inventories and forest statistics (including FAO forest resource assessment (FRA) and other FAOSTAT statistics)
2. Spaceborne remote sensing
3. Airborne remote sensing
4. Spatial datasets for land cover and land use
5. Forestry production and income statistics from the national accounts
6. Non-forest statistics
7. 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 (e.g. thinning, 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 (FAO) provides 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 comprises a series of variables related to forestry production and forestry trade flows.

Additionally, the FAO issues a Forest Resources Assessment (FRA) report every 5 years (www.fao.org/forestry/fra/en/). The data in the FRA originate from country reports and remote sensing and contain data on forest land, timber, employment, and other forest-related topics.

Notwithstanding the suitability of forest inventories data for constructing the 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.

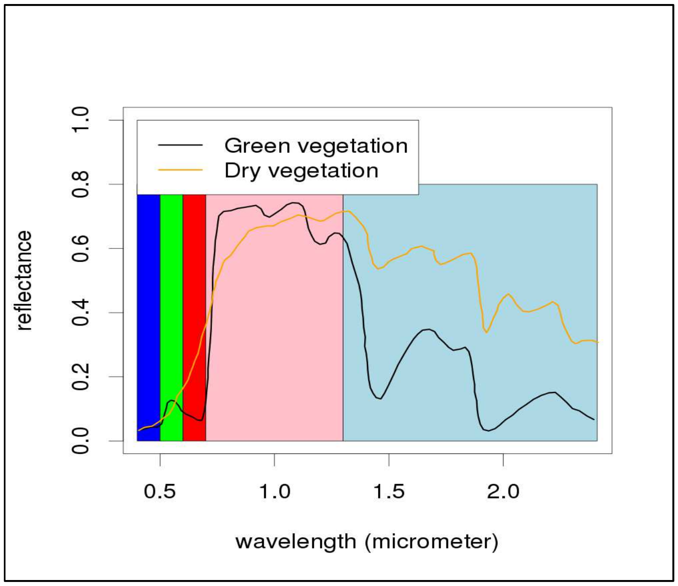
Also, the nation-wide nature of the information included in FRA may not be detailed enough to support specific policy applications, which is an important goal of forest accounting. In this respect, the data from inventories might be combined with routinely gathered forest statistics by the national forest 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 the NOAA 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 the 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 5.1 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. Figure 5.1 shows the reflectance pattern of green healthy vegetation and dry vegetation.

Figure 5.1: Typical reflectance pattern of vegetation



Source:??

The developments in spaceborne RS are ongoing and have seen a surge in applications because of increases in computational power and the need for addressing 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, USA, Brazil and Russia. Three particular features of spaceborne RS stand out:

a. *Georeferencing:* One can think of forests as spatial entities. Many of the environmental services provided by forests are related to the forest's 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. One can therefore combine remote sensing imagery 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.

b. *Spatial and temporal resolution:* 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 the 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 tradeoff in that high spatial resolution accompanies low temporal resolution and vice versa.

c. *Affordability:* In addition to the suitability of the technical aspects of RS for studying vegetation, it is also relatively inexpensive to access RS data. High resolution data or on-demand delivered data offer valuable information that serve 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 5.1. In addition to the growing access to RS data sources it is important to mention that software options for managing geographic information has been growing as well. In particular, free and open source options are becoming more available (10).

Table 5.1: 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 deliering 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 aircrafts.	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 preference greater accuracy in data collection. Therefore, one may select remote sensing products offering high spatial resolution. In this respect, 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 combined with forest inventory plots (12). However, a moderate to high temporal resolution may be required for certain measurements in forest accounting. In particular, estimation requiring the analysis of time series will require higher temporal resolution. For example, the assessment of trends in forest ecosystem productivity by means of time series of RS-derived biophysical parameters, or the segmentation of vegetative areas by function of phenology, should have a temporal resolution of ??

Airborne remote sensing

Airborne remote sensing (RS) 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(6). Data from LiDAR systems can be used for segmenting 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 country or region 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 level estimates, land cover maps allow the derivation of the spatial distribution of ecosystem services related to specific forest ecosystems. This is a fundamental input towards the quantification and understanding of linkages between forest resources and 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 a local level. However, where local classification systems are used it is highly recommended to embed or concord 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, particular in relation to comparisons across different areas and ecosystem types and over time.

Forestry production and income statistics from the 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 important flows are recorded in the national accounts. Therefore, a country's national accounts constitute an important data source for information on flows of forest goods to the different economic sectors. The information in the national accounts can also be the basis for a regional analysis of flows of forest goods and services. If data on the spatial distribution and size of companies are available, the demand of companies for forest goods and companies can be tracked to the different forest ecosystems across the country or region under consideration.

Non-forest statistics

There is a large and varied set of data sources that can support the elaboration of forest physical accounts. Some examples are:

- Livelihood and household surveys: rural populations demand goods and services that are related to both forests and trees outside forests. For trees outside forests 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 are more likely registered in surveys addressing livelihood-related issues.

<< Insert Box 5.1 giving example of country livelihood survey or equivalent with information on forest incomes etc. – possibly Vietnam>>

- Economic statistics: Although many forest products are part of the 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. For instance, 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 in which forests are located. Separately, studies may also be completed on the health benefits to populations 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 agro-forestry 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.

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 (i) other landscape elements and topographical features and (ii) the spatio-temporal context in which they exist. Both of these factors will have considerable impact on the assessment of the relative importance of forests 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 are important as well (i.e. municipalities, districts, counties, etc).

5.3 Compilation of asset accounts

Typical indicators and data sources

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, m^3) depending on the resource(s). Table 5.2 presents the basic components of the asset accounts and a non-exhaustive list of indicators and potential data sources.

Table 5.2: Typical indicators and data sources for constructing the forest asset accounts.

A: Assets accounts based on forest land, and B: Assets accounts based on standing timber

A. Forest land		
	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. 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	• Havested timber during the period (m^3)	1, 5
• Tree losses	• Losses in timber volume due to fires, disease, catastrophic events, etc (m^3)	1
Closing stock of standing timber		
*Data source: 1. Forest inventories and forest statistics (incl 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		

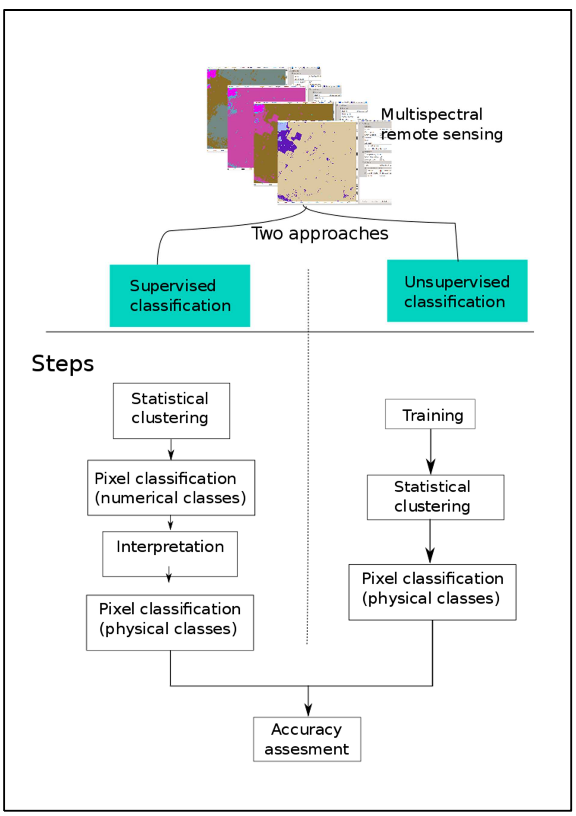
Approaches to land cover mapping

When following an ecosystem-based approach, land cover, land use, and forest maps are essential data sources. Land cover maps constructed at national or sub-national 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, one can consider obtaining an approximation of the location and extent of forest land from global land cover maps like ESA's Globcover (3), the MODIS land cover product, Ecoclimap (1), 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 5.2.

Figure 5.2 Methodological approaches to land cover mapping

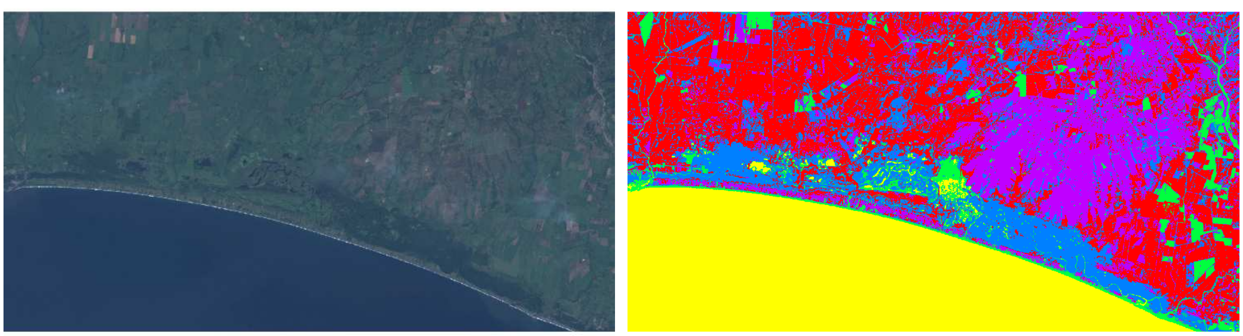


In the supervised classification approach, one starts from existing knowledge about the correct classification based on a number of sites in the area of interest. This information is registered such that the reflectance values of the known locations are associated with the land cover classes of those 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 such that all pixels in the area of interest are assigned to one of land use classes. In a 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 such 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 5.3 provides an example of this classification approach. The region of study is the Pacific coast in South-Eastern 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. Figure 5.3A shows the area as seen by Landsat 8 in real color and Figure 5.3B 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 5.3B in light-blue. 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 that class presented different degrees of bare soil influence and humidity.

Figure 5.3: Unsupervised classification with an arbitrarily defined five classes in a coastal region in South-Eastern Guatemala

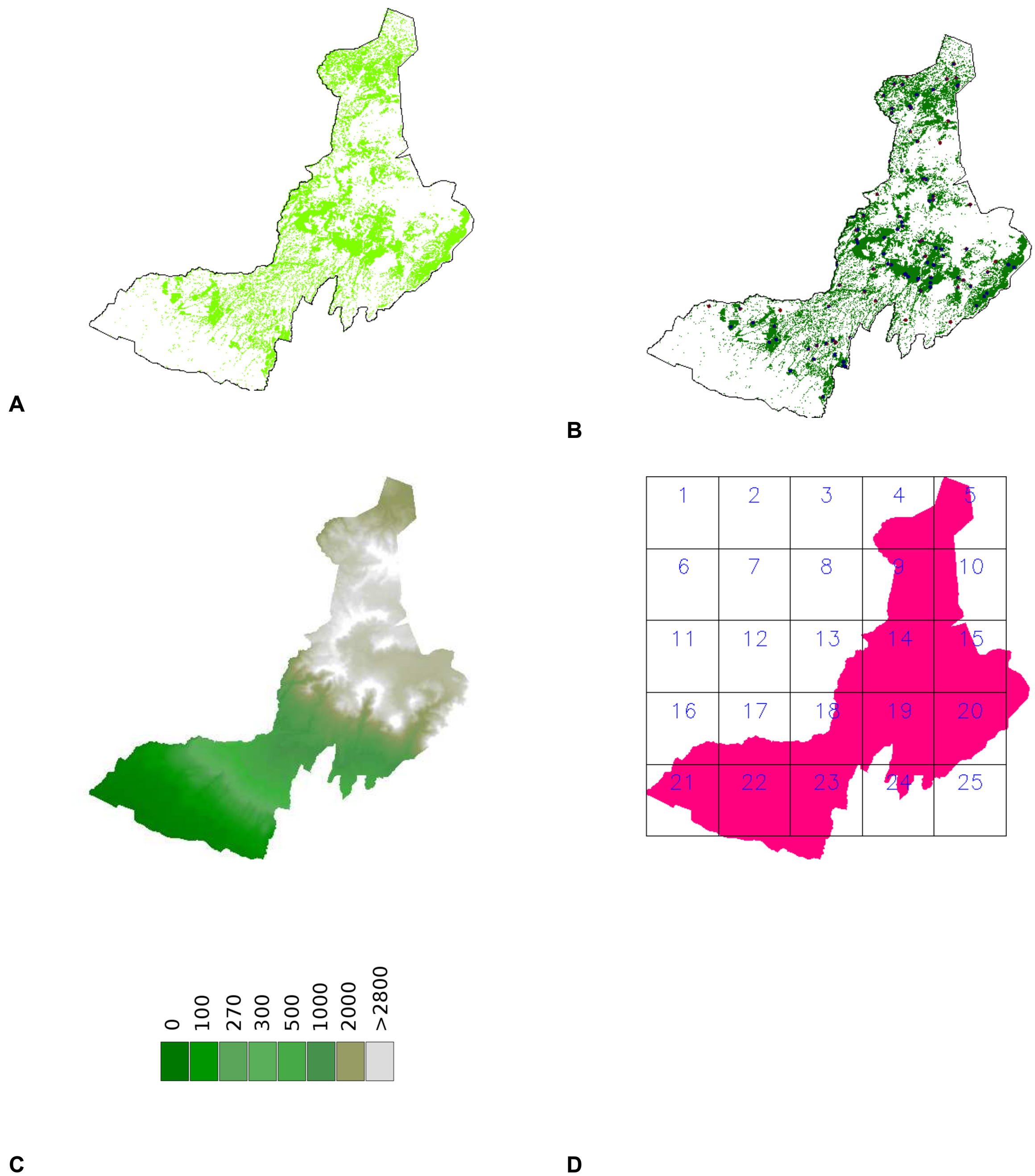


A **B**

Conducting this kind of analysis at different timestamps allows the assessment of gains and losses in the extent of forest land 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 (2) present a review on different methods of digital change detection for ecosystem monitoring.

For illustrative purposes, Figure 5.4 shows a hypothetical area where forest cover has been monitored. The status of forest cover is presented for two timestamps, Figure 5.4A and 5.4B, which are taken, respectively, as the beginning and the end of the accounting period. The change recorded by the end of the accounting period is indicated in Figure 5.4B (losses in red, gains in blue). Additionally, maps on the elevation and a grid-like zoning of the area are presented.

Figure 5.4: Hypothetical region. A. Forest cover at the beginning of the accounting period; B. Forest cover and location of gains (blue) and losses (red) by the end of the accounting period; C. Elevation in meters above sea level; D. Zoning for landscape analysis



Forest land asset accounts

Table 5.3 presents the general forest asset account for the region and accounting period under study. The data in Table 5.3 are an example of the simplest way forest asset extent accounts can be presented. 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, e.g. due to fires, expansion of agriculture or urban areas, harvesting, etc.

Table 5.3: General forest land asset account for a hypothetical area and one accounting period

	Forest land (ha)
Opening stock	59498.37
- Additions	1554.21
- Reductions	3118.32
Closing stock	57934.26

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 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 5.4C and 5.4D is useful to exemplify the importance of partitioning the study area in smaller regions. Figure 5.4C is the digital elevation model of the region and allows partitioning the area in altitudinal strata. Figure 5.4D 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 5.4 presents the results of using the digital elevation model from Figure 5.4C to assess changes in forest land 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 5.4 show that the intensity of additions and reductions with respect to the opening forest land stock was not equally distributed across the study area. Forest land reductions were greater than the additions in three out of four altitudinal ranges.

Table 5.4: Forest land asset accounts by altitudinal range (hectares)

	Altitude (metres above sea level)				
	0 - 500	500 - 1500	1500-2500	> 2500	TOTAL
Opening stock	10396.89	10920.06	17102.52	21078.90	59498.37
- Additions	244.17	311.04	408.60	590.40	1554.21
- Reductions	572.58	273.87	1186.65	1085.22	3118.32
Closing stock	10068.48	10957.23	16324.47	20584.08	57934.26

Table 5.5 presents data on forest land stocks when the study area is partitioned according to the grid shown in Figure 5.4D. 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 5.5: Forest land assets per grid units according to the partition presented in Figure 5.4D

	Grid unit reference number								
	u4	u5	u9	u10	u13	u14	u15	u16	u17
Opening stock	4531.05	3412.35	4152.24	1683.72	1953.72	7448.22	2599.29	106.92	1955.07
Additions	91.26	94.41	149.04	85.32	42.57	192.15	76.50	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	4407.75	3357.81	4086.09	1753.38	1817.10	7208.10	2523.96	139.59	2001.15
	u18	u19	u20	u21	u22	u23	u24	u25	TOTAL
Opening stock	4979.61	8809.47	7778.88	108.90	3719.79	5382.99	694.44	181.71	59498.37
Additions	66.06	221.04	198.63	0.00	19.44	174.15	0.00	17.73	1554.21
Reductions	84.87	650.07	373.68	0.00	242.73	358.29	0.00	3.87	3118.32
Closing stock	4960.80	8380.44	7603.83	108.90	3496.50	5198.85	694.44	195.57	57934.26

Indicators of forest condition

Together with reporting opening and closing stocks and the source of additions and reductions in forest land 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 5.6 presents a short list of common characteristics in the assessment of forest ecosystem condition together with a number of proposed indicators and potential data sources.

Table 5.6: Parameters of forest ecosystem condition, indicators and possible data sources

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

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

** 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 pollutants

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 by 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; for instance MODIS LAI product (https://lpdaac.usgs.gov/products/modis_products_table/mod15a2), Geoland2 (www.geoland2.eu) and Global Land Surface Satellite (GLASS) 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 fires 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. For instance, 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, allows for the spread of invasive species from disturbed edges (11), 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. In measuring forest fragmentation 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 are possible including 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 more 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 5.7 and 5.8 present the values of a number of fragmentation indicators for the hypothetical example depicted in Figure 5.4. 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 5.8 which are based on the smaller grid units from Figure 5.4D, show the forest cover dynamics more clearly and support interpretation of the ecological and policy-related implications of changes in forest cover.

Table 5.7: Indicators of forest fragmentation at the beginning and end of the accounting period for four altitudinal strata of the studied region

Altitude (metres above sea level)	Beginning of the period				End of the period			
	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	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 5.8: 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

Unit	Beginning of the period				End of the period			
	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	3635.4	3963.9	0.142	35.7	4076.2	3593.8	0.201
5	10.3	1562.5	852.1	0.757	10	1568	827.5	0.76
9	14.1	2067.7	425.8	0.901	13.3	2002.5	383.2	0.91
10	12.7	1576.2	306.4	0.827	13.5	1646.2	377.0	0.795
13	90.7	5687.7	842.9	0.578	74.4	5258.4	584.0	0.686
14	32.5	2941.1	1201.7	0.843	30.3	2909.3	1064.7	0.856
15	11.6	1487.9	435.1	0.837	11.1	1491.5	390.7	0.85
16	1.6	487.3	3.8	0.975	2	513	15.1	0.917
17	8.4	1175.8	173.7	0.915	8.7	1216.2	191.9	0.908
18	10.1	2011.7	1307.2	0.741	9.9	1989.8	1122.5	0.777
19	19.1	2023.2	4141.8	0.541	18.5	2121.1	3647.8	0.576
20	27	2629.4	2681.6	0.664	25.5	2599	2407.8	0.691
21	1.2	383.9	3.4	0.969	1.2	383.9	3.4	0.969
22	8.7	1111.6	942.3	0.748	8.1	1120.7	862.4	0.755
23	10.9	1934.9	751.0	0.865	10.4	1925.1	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

5.4 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 5.9 presents a series of possible indicators for the ecosystem services associated with forest ecosystems. The list of indicators in Table 5.9 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.

Table 5.9: 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); Number of units	1, 4, 5, 6
• Genetic material	• Composition • Diversity	6
• Grazing	• Number of animals in silvo-pastoral system • Weight units of produced animal product • Energy uptake	6
Regulating services		
• Atmospheric/climate regulation	• Net carbon storage (gains-losses)	2, 6, 7
• Water flow regulation	• Canopy cover fraction in recharge areas • Average daily and annual water flow in rivers • Cover in strategic locations (floodplains, steep slopes, wetlands, etc)	2, 6, 7
• Water cycle regulation	• BOD • Turbidity in waterways	2, 6
• Pollination	• Abundance and variety of pollinator species	5, 7
• Soil retention and formation	• Erosion rates • Cover (or bare soil) fraction in vulnerable areas • Turbidity in waterways	7
Cultural services		
• Recreation	• Number/area of national parks • Area of parkland within cities	5, 7
• Information and knowledge	• -	
• Spiritual and symbolic	• -	

*Data source: 1. Forest inventories and forest statistics (incl. FRA and other FAOSTAT statistics); 2. Spaceborne remote sensing; 3. Airborne remote sensing; 4. LC/LU maps; 5. National accounts; 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 (NTFP) varies considerably among regions. Depending on the relevance and the market value of NTFP, 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 NTFP; 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 entails exploring a more diverse range of methods and data sources. The measurements and modeling schemes often encompass other disciplines like hydrology, physics, edaphology, geostatistics, amongst others. As such, incorporating theses flows in the forest physical accounts requires the integration of multidisciplinary teams and inter-institutional 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, etc. are all relevant components within forest flow accounts. In addition, the 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 the soil (8). 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 (5) propose a methodology that combines field surveys and RS. FRA data have also been used for estimating carbon gains across the European Union countries (9).

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 (7) and modeling approaches where forest productivity is derived from energy reflectance and ancillary data.

Regarding the role of forest land 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 SWAT (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 (i.e. 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 equation estimates average annual soil loss (A) as the multiplication of 5 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 by other 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 like turbidity and biochemical oxygen demand (BOD).

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 (e.g. 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 where 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 population of potential visitors and 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 and publicly available datasets like Open Street Map (www.openstreetmap.org) can be useful in obtaining road network data.

In addition to the modeling alternatives mentioned in previous paragraphs, it is important to underline recent modeling efforts towards the description of ecosystem services like the Artificial Intelligence for Ecosystem Services (Aries - http://www.ariesonline.org) and the Social Values for Ecosystem Services (SolVES - http://solves.cr.usgs.gov/). Aries is a modular set of deterministic and Bayesian modeling tools including, amongst 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.

5.5 Challenges

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

Developments in RS 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 the usability of RS data is not free of errors and the reliability and comparability of measurements is dependent on many factors including atmospheric conditions, cloudiness, slope and shadow effects, illumination conditions, etc. There are also particular difficulties in translating information about a 3 dimensional world into 2 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. Therefore, data comparison across time is of paramount importance in forest accounting. 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 thereof).

6. Compiling monetary accounts for forests

6.1 Background

In order to aggregate measures of forest resources and ecosystem services and to compare them to 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 facilitates integration with the standard economic accounts of the SNA.

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

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, they can only be valued through the benefits they provide to humans. For those 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.

In what follows we discuss what can be valued before outlining how to value these benefits by describing the valuation principles of the SNA and SEEA Central Framework and the available valuation approaches. We then show in more detail how market, quasi-market and non-market benefits from forests can be valued and how such estimates cam be integrated asset and flow accounts. We will briefly outline how to compile forest related environmental activity accounts before some of the challenges will be discussed.

6.2 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 where ecosystem services contribute or are inputs to the value of benefits. These benefits comprise goods and services that directly generate utility and alter human welfare. Benefits may be:

- 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.
- consumed directly by households from the environment and hence represent final goods and services. Household collection of mushrooms and berries from forests are examples. These final goods and services would be considered part of economic production in the SNA.
- outside the production and income boundary of the SNA that are either (i) used, perhaps unknowingly, by economic units within their production processes (e.g. soil retention and water flow regulation by upland forests) or (ii) consumed by households or society as a whole (e.g. 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 benefit and to estimate the value of the associated ecosystem service – i.e. 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 a relevant value and the value of the associated ecosystem service must be found.

The ecosystem services described above 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 concept 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 and this possibility is not discussed further in this chapter.

Generally speaking, the value of forests can be considered in terms of (i) direct use values (through their consumptive and non-consumptive use), (ii) indirect use values (through contributing to other goods and services with direct use value) or (iii) non-use values (any intangible benefits people enjoy) attached to them (TEEB 2010[12]). Each of these types of value will have a connection to different types of benefits and hence to the underlying ecosystem services.

The first two columns in Table 6.1 give a condesnsed overview of the connections between forest benefits and forest ecosystem services. It is important to recognize that there can be different beneficiaries from these ecosystem services. The beneficiaries include those in the forestry industry (logging companies, wood production) and those in other industries (e.g. hydropower companies, agricultural producers, municipal water supply, tourism). The beneficiaries may range from local (forest land user, downstream municipality) to a national and even global level.

Table 6.1: Overview of forest ecosystem services and benefits and their inclusion in the SNA

Forest Ecosystem Services	Forest Benefits		SNA Production Account
timber (P)	timber	market benefits: market goods and services produced by forest activities	explicitly measured if resulting in (i) market-production (sale/barter), (ii) production of goods for own final use
firewood/charcoal (P)	wood-based energy		
other NTFP (P)	food, fodder, medicine		
carbon storage/ sequestration (R)	climate regulation		not included
genetic material (P)	product development	quasi-market benefits: contribute to the production of market goods and services produced by other economic activities	implicitly measured through the value of non-forest (i) market-production (sale/barter), (ii) production of goods for own final use
biomass for grazing (P)	livestock production		
pollination (R)	agricultural production		
water flow regulation (R)	agricultural production flood protection		

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

Forest Ecosystem Services	Forest Benefits		SNA Production Account
	hydro-power production		
soil retention and formation (R)	sedimentation control		
water cycle regulation (R)	(drinking) water supply		
recreation (C)	tourism		
information and knowledge (C)	research/ education		
spiritual & symbolic (C)	cultural heritage, identity, spiritual/ religious functions	non-market benefits: do not contribute to goods or services traded at markets	not included
non-use (C)	existence/ bequest/altruist		

6.3 Market, quasi-market and non-market benefits

In applying valuation techniques, it is useful to differentiate between three different types of forest benefits: market benefits, quasi-market benefits 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 6.1. 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. Market benefits can be linked to two main types of ecosystem services:

(i) *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 NTFP. The private goods are explicitly measured as forest-related benefits in the SNA if they result in market production or production/consumption on own account.

(ii) 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. These types of market benefits are not yet included as outputs from production in the SNA.

Quasi-market benefits

Quasi-market benefits are those benefits provided by ecosystem services that in turn contribute to the production of market goods or services by other economic activities. For example, 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:

(i) *Substitutable ecosystem services that are inputs to non-forest production*: These services can include water cycle regulation increasing drinking water quality (reducing need for water treatment), water flow regulation providing water to agriculture (reducing irrigation needs) or soil retention control reducing sedimentation (reducing dredging or protection infrastructure needs).

(ii) *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.

(iii) *Attribute of a heterogeneous non-forest market good*: These ecosystem services are recognised 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 services with public good characteristics. These services include cultural heritage, local identities, 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 which 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 the use of “non-market” 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 are prices that are not “economically significant”. Examples of national accounts non-market pricing includes government provision of health and education services.

6.4 National accounts valuation concepts and principles

General concepts

To ensure compatibility with SNA estimates, valuation of forest resources and ecosystems need 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, i.e. 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 to market prices (SNA, 2008, 3.123).

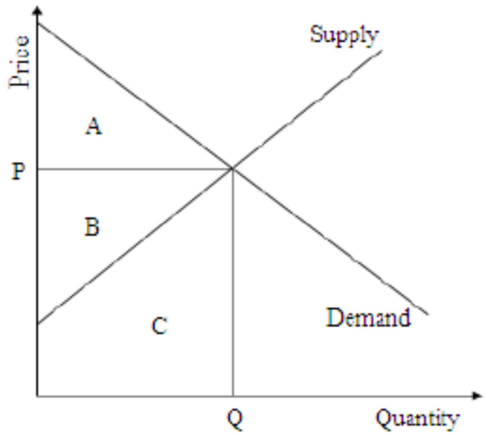
In neoclassical economics, exchange values result from the price (*P*) and the quantity (*Q*) exchanged at the equilibrium of supply and demand (see Fig 6.1). Without going into details, area *A* reflects the consumer surplus arising from a price lower than the consumers' willingness to pay which should 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 equal their marginal production costs, *C* (as portrayed in their supply curve). The value entered into the SNA is *P*Q* or *B+C* in Fig 6.1. 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 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 (thus include area A in Fig 6.1). Social values aim to capture the ecosystem services that never enter markets due to the presence of externalities or market imperfections.

Although following the standard valuation principles of the SNA these additional values are not captured there is ongoing discussion, in the context of the SEEA EEA, of whether through the concept of ecosystem services, it is possible to estimate exchange values for forest ecosystem services that are not directly traded in markets. This will be discussed further in sections 6.3 and 6.4.

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 6.1: Consumer surplus (A), producer surplus (B) and production costs (C).



It has been argued that for the same market good different prices may be recorded according to the price function that arises in some particular market situations (see Day 2013).[14] Hence, depending on the market institutions and the level of price discrimination, prices need not be constant at *P* as shown in Fig 6.1. Rather they would vary with the consumers' willingness to pay in order for the producer to "capture" the consumer surplus. Thus, in situations of very high degrees of price discrimination, i.e. 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, there are three ways to estimate exchange values for forest products and ecosystem services.

(i) *Market prices*: Goods and services exchanged in markets can be valued based on their observed market price. Strictly speaking, market prices are defined as amount of money that willing buyers pay to acquire something from willing sellers (SNA 2008: 3.119).

(ii) *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.

(iii) *Cost of production*: Alternatively, these goods and services can be valued by the sum of all costs of producing the good (e.g. land rents, machinery and labor costs).

[14] Day, B., 2013. An overview of valuation techniques for ecosystem accounting. Issue Paper 1.1, Valuation for Accounting Seminar. November 2013.

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), in estimating the 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):

> (i) *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 Central Framework 5.6).
>
> (ii) *Written down replacement cost*: The current acquisition price of an equivalent new asset less accumulated consumption of fixed capital. When reliable, 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. However, since forest land is not depreciable this method is not appropriate for forest valuation.
>
> (iii)*: Net Present Value (NPV)*: The discounted value of future returns from forest resource stocks or the discounted value of all flows of ecosystem services from forests (see Box 6.1)

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

For the valuation of forest land other considerations need to be taken into account. In principle the value of the timber resources should be valued separately from the land "under" the timber resources themselves. This separation 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 forest land may however be challenging. In some cases, where the only relevant income stream is from harvesting timber then the value of the land itself may be very low and hence the value of forest land and the value of timber resources are effectively the same. On the other hand where forest land 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 forest land and this information can be used in determining appropriate values.

Where forest land values are not directly observed (e.g. via land markets), estimating the benefits from alternative land used 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 bound on the value of the forest land.

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.

Forest land 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 area of forest land. However, the potential trade-offs between different ecosystem services (e.g. between timber extraction and carbon storage) need to be considered when making projection 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.

Box 6.1 Calculating net present values (NPV)

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:

(i) *Current and expected returns on resource stocks or forest lands*: Returns are defined as the economic rent or surplus value that is attributable to the timber resource or ecosystem service. For resources there are a number of standardized approaches to calculate resource rents (e.g. residual value, appropriation and access price method; see SEEA Central Framework, 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 (see section 6.2).

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, and 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.

(ii) *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 a 20 time span do not affect the NPV, but this depends on the choice of the discount rate. Where future extraction or use patterns are known (e.g. 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.

(iii) *Discount rate*: To value future returns at their present value, the returns need to be discounted. A discount rate expresses time preference (i.e. how far one 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. 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 to measures of production and income, for example for estimating productivity. However, for other analysis it may be relevant to apply social discount rates which take into account more explicitly long-term values to society. SEEA Central Framework Annex A5.2 explains relevant considerations.

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

6.5 Methods for valuing ecosystem services and benefits

There are a number of well-established valuation methods that have evolved and have been widely applied in environmental and ecosystem service valuation. Most of these techniques are, however, not explicit, about the extent to which they are consistent to 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 provides discussion on the application in an accounting context.

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 (ref). 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 is 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.

(i) *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 and 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 derive 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 forest land.
- *Access price method*: Resource rent is based on payments for the purchase of licenses or quotas to access a forest area.

Where market prices include rents for labor and other asset, 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 (e.g. over-harvest of forest resources) or ecosystem degradation.

(ii) *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 a water treatment plant filtering water, 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 due to landslides caused by from 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 methods can be used for valuing quasi-market benefits.

(i) *Production/Cost/Profit function methods* estimate the value of an ecosystem service by recognizing the ecosystem service as an input into the production of a market good or service (e.g. 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.

(ii) *Hedonic pricing methods* derive the implicit price for an ecosystem service by modelling land values on a set of explanatory variables (characteristics of the land) including ecosystem related proxies. Hedonic pricing has been mostly applied in context of well-established property markets to price characteristics such as cleaner air.

(iii) *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.

(iv) *Averting behavior methods* analyze individual choices to improve certain outcomes. From data on expenditure for certain measures (e.g. install water filter to reduce pollutants in drinking water at home), the willingness-to-pay for an ecosystem service (e.g. water filtration) 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 there are a number of concerns that have been raised in applying these approaches in an accounting context.

(i) *Contingent valuation methods* (CV) 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.

(ii) *Choice experiments* (CE) analyze decision-making processes from data related to people ranking/choosing of 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 described above can all be designed to estimate a range of different values and ecosystem services. Ideally, the methods would be implemented through the collection of data pertaining to specific ecosystem locations and/or specific ecosystem services. Given the time and cost implications, and given the growing body of valuation studies, benefit transfer methods become more prominent. These methods support the use of information from one location or ecosystem in the valuation of similar ecosystems in other locations. Four benefits transfer methods are described below. Since various assumptions are needed to apply any of the methods care should be taken in their application and in the interpretation of results.

(i) *Unit benefit transfer method* simply takes the unit value of forest benefits (e.g. per hectare 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.

(ii) *Adjusted unit transfer methods* adjust the same unit value by controlling for economic conditions (e.g. living standards) or ecosystem characteristics (e.g. tree coverage).

(iii) *Value/demand function* transfer methods apply parameters from an original study determining the importance of ecosystem characteristics though a demand or value function (e.g. to impacts of slope and rainfall on soil retention control values). These parameters are then combined with data from the forest ecosystem.

(iv) *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 (TEEB) initiative.[15]

[15] The database is available at http://www.fsd.nl/esp/80763/5/0/50.

6.6 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 6.2 gives an overview of how different forest resources and ecosystem services can be valued. A number of academic case studies and project evaluation exercises have been applying these techniques.

Table 6.2: 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 NFTP	X	X						X
Climate regulation and other regulating services (part)	X	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
								X
Non-market benefits								X
Cultural benefits						X	X	X

Valuing market benefits

Ideally, forest accounts would identify three components of the value of forest goods and services (Lange 2004):

(i) the *production value* is the total quantity sold or used times its unit value (i.e. *P*Q* or *A+B* in Fig 6.1)

(ii) 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.

(iii) the *resource rent* or in-situ value contributed by forest ecosystem services, the value of the product generated minus any production or extraction cost (i.e. *A* in Fig 6.1).

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 6.2).

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 Central Framework, chapter 5.8 and Lange 2004, chapter 7.1). Resource rent on timber can be derived as follows:

(i) *Appropriation methods*: In some instances resource rents rent can be estimated directly by using estimates of the stumpage price, i.e. the amount paid per cubic metre of timber by the harvester to the owner of the timber resource (SEEA CF 5.380).

(i) *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 Central Framework 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 (mathematical details are given in Lange 2004: Box 7.1):

(i) 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.

(ii) 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.

(iii) The *Consumption value approach* is a variant of the stumpage value approach where 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 NTFP

The resource rent generated by NTFP 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 NTFP are exchanged in formal markets and result in monetary transaction they are reported in the SNA. Yet often NTFP, especially in developing country contexts, are exchanged in informal markets or used to meet subsistence needs being produced or extracted for own-use (e.g. collection of firewood from a nearby forest). The SNA has established principles for the inclusion of such non-monetary transactions allowing three different approaches:

(i) *Unit resource rent approach:* Even if NTFP are widely used for informal exchanges or self-consumption, market prices for the same or very similar product can be observed nearby (e.g. buying charcoal at a local market). Local market prices for these goods may be used to value non-market production taking care to account for regional variations in prices.

(ii) *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.

(iii) *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 is labor, products may be valued at the opportunity cost of the time it takes to gather them. An average local wage can be used, which is adjusted for factors 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 NTFP, 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 contexts, the distinction between total value-added and in situ value is highly sensitive to the assumptions made about the opportunity cost of labor. Only where there is extensive commercialization of forest products, other costs, such as transportation, may become important.

Often estimates rely on local surveys of household NTFP extraction and self-consumption and sales (such as in Godoy et al. 2000[16]; Schaafsma et al. 2012[17]). 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 which 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.

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Valuing climate regulation and other regulating services

Given the importance of carbon sequestration and storage for climate change mitigation, there are a number of market-based solutions 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 considered, up-to date there are no-commonly agreed accounting standards for its valuation. With an increasing number of countries interested to take part in REDD+ activities, this, however, becomes increasingly important. For the valuation of carbon related ecosystem services (carbon sequestration and carbon storage) some different options may be possible:

(i) *Damage cost approach:* This approach estimates the costs of the global damage from climate change averted by reducing emissions by a unit (e.g. tonne) of carbon. This value corresponds to a social value concept. Exchange values are unlikely to be equivalent to these costs. The US government recently decided to use a range of estimates centered at $21/tCO2 in cost-benefit analyses.

(ii) *Production costs approach:* The costs of avoiding climate damages can be estimated through the costs of climate change mitigation. These mitigation costs can be based on the production cost of reducing emissions from deforestation and forest degradation, most of all the opportunity costs from not converting forest land into other uses (see for detailed guidance World Bank, 2011[18]). 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.

(iii) *Rents*: If market-based mechanisms are established rents per land unit can be calculated based on the carbon sequestered and stored in above and below ground biomass. Payment levels per unit of carbon could be based on:

- *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 a future REDD+ mechanisms. There are already a number of voluntary carbon markets that trade carbon offsets. In 2011 carbon credits generated from REDD+ projects have ranged between $4 and $11.5 per tCO2 emission reductions over the whole project lifespan (Peters-Stanley et al. 2012[19]).

- *Payments for emission reductions*: Carbon sequestration and storage could also be priced if payment were made to land users through direct transfers from a national or international climate fund, as is also 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

[18] The World Bank. 2011. Estimating the opportunity costs of REDD+. A training manual. World Bank Institute, Washington DC.
[19] Peters-Stanley, M., Hamilton, K., Yin, D., 2012. Leveraging the Landscape State of the ForestCarbon Markets 2012. Ecosystem Marketplace

purposes. Nonetheless, using these values is problematic as payments are often not outcome based (i.e. conditional on the actual ecosystem services delivered), but activity-focused (i.e. conditional on a certain land use practice which sometimes has not 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 bio-prospecting schemes that grant research institutions or private companies the right to use. Despite of being widely appraised as a potential market solution for conserving forest biodiversity in the 1990s, they have only found limited application.

Valuing quasi-market benefits

Depending on the type of quasi-market benefit, they can be valued using different valuation techniques, based on cost-based or revealed preference methods (see Table 6.2). 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 portioning 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 constitute 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 the following cost-based approaches:

(i) *Replacement cost method*: The values of ecosystem services can be valued through the observed expenditure for activities undertaken to compensate for a decline in the supply of this ecosystem services. Examples include: costs of switching to alternative water sources or costs of water treatment when water quality in one source deteriorates, increased irrigation costs when water flows fluctuate, dredging costs to remove soil sedimentation, or building landslide protection mechanisms in areas prone to soil erosion.

(ii) *Damage costs*: Alternatively, the same ecosystem services could be valued through their damages caused by their loss, such as health impacts due to 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 ecosystem services can cause damage costs, but these can only be estimated through production functions.

(i) *Production function method*: 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[20], soil retention and increased farm productivity[21], hydrological services and agricultural production[22] as well as hydropower generation through reduced soil sedimentation[23]. 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.[24] [25]

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 education institutions (universities, schools) can benefit from.

Income flows related to forest-based tourism and research and education are recorded in the SNA through a number of related industries, such as hotels, accommodation, 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. However, where these payments are not required, special valuation techniques are needed.

(i) *Hedonic price method* have 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 (e.g. proximity to forest or presence of unique animal or plan 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 country contexts, the data available to apply this method will not provide a sufficient sample size.

(ii) *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. There are several shortcomings though. Firstly, travel costs only represent part of the full costs incurred. And

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[24] Costello, C., Ward, M.B. (2006) Search, bioprospecting and biodiversity conservation. Journal of Environmental Economics and Management 52(3): 615-624
[25] 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.

more importantly, it only relates to the benefits experienced in one specific site (e.g. having access to a certain area of natural forests) and does not compare to other sites (e.g. having access to a larger area of natural forest somewhere else). 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.

(iii) *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 CV in Costa Rica[26] and Bolivia[27] and CE in Uganda.[28] In order to derive values that are compatible with SNA estimates, stated preference need calculate marginal values. Such values can be calculated through a special framing of the survey questions (e.g. 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 rainforest or the existence and/or altruist value for a consumer in Europe from knowing that this rainforest 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.

(i) *Stated preference methods* can return values for any ecosystem service based on the consumers' choices of different scenarios in hypothetical market contexts (e.g. choose 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.[29]

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

[26] Chase, I.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.

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

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6.7 Challenges

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

(i) it is often difficult to quantify ecosystem services and the benefits from them and the data availability in many developing countries is rather weak,

(ii) the methods and underlying assumptions can vary so that monetary estimates are often not comparable,

(iii) many valuation studies do not follow the SNA principles so that values are not comparable to national accounts data; and

(iv) 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, including:

(i) direct market valuation methods rely on observable market data which is often not available for ecosystem services;

(ii) 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;

(iii) stated preference methods have been challenged for their hypothetical nature and their technical complexity;

(vi) 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 estimates for a number of study sites to a whole country.

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

- Marginal values (i.e. the value of small incremental changes in land use) are more meaningful in informing policy decisions than absolute values or average values, but are 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 (e.g. flow of water or sediments through space).
- 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.
- Estimation using exchange values only will likely under-value 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 that 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 (e.g. commodification of nature)
- Monetary valuation ignores multiple dimensions of human well-being and the plural ways values are expressed.

References

(to be completed)

Wealth Accounting and the Valuation of Ecosystem Services

Wealth Accounting and the Valuation of Ecosystem Services (WAVES) is a global partnership led by the World Bank that aims to promote sustainable development by ensuring that natural resources are mainstreamed in development planning and national economic accounts.

www.wavespartnership.org

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