System of Environmental-Economic Accounting 2012

Experimental Ecosystem Accounting

United Nations

European Commission

Food and Agriculture Organization of the United Nations

Organisation for Economic Co-operation and Development

World Bank Group

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Foreword

1. Comparable and reliable data supporting coherent analytical and policy frameworks are essential elements in informing debates and guiding policy related to the relationship between the economy and the environment.

2. The System of Environmental-Economic Accounting 2012—Experimental Ecosystem Accounting (SEEA Experimental Ecosystem Accounting) presents initial efforts to define a measurement framework for integrating biophysical data, tracking changes in ecosystems and linking those changes to economic and other human activity. It applies the accounting concepts and rules to the emerging field of ecosystem assessment and measurement in response to a wide range of demands for integrated information related to environmental sustainability, human well-being, and economic growth and development. SEEA Experimental Ecosystem Accounting has been produced and is released under the auspices of the United Nations, the European Commission, the Food and Agriculture Organization of the United Nations, the Organisation for Economic Co-operation and Development, and the World Bank Group.

3. SEEA Experimental Ecosystem Accounting complements the conceptual framework and accounts presented in the international statistical standard for environmental-economic accounting, the System of Environmental-Economic Accounting 2012—Central Framework (SEEA Central Framework). The SEEA Central Framework starts from the perspective of the economy and its economic units, and incorporates relevant environmental information concerning natural inputs, residual flows and environmental assets. The SEEA Experimental Ecosystem Accounting starts from the perspective of ecosystems and links ecosystems to economic and other human activities. Together these approaches provide the potential to describe in a complete manner the relationship between the environment, the economy and other human activity.

4. SEEA Experimental Ecosystem Accounting reflects a synthesis of current knowledge in the measurement of ecosystems. While it represents a convergence of disciplines across ecology, economics and statistics on ecosystem accounting, there are important measurement and conceptual challenges which remain. Experimentation and further engagement across disciplines and organizations is paramount in advancing the research agenda and reaching a broad-based consensus on selected modules of SEEA Experimental Ecosystem Accounting.

5. The United Nations Committee of Experts on Environmental-Economic Accounting (UNCEEA) managed and coordinated the work as mandated by the Statistical Commission at its thirty-eighth session in 2007. National statistical offices and international organizations made valuable contributions. Expert groups carried out research on ecosystem accounting issues. During the drafting of SEEA Experimental Ecosystem Accounting, a draft text was posted on the website of the United Nations Statistics Division for worldwide comment, thereby achieving full transparency in the process.

6. At its forty-fourth session in 2013, the United Nations Statistical Commission welcomed SEEA Experimental Ecosystem Accounting as representing an important first step forward in the development of a statistical framework for ecosystem accounting and encouraged the use of SEEA Experimental Ecosystem Accounting by international and regional

agencies and countries wishing to test and experiment in this new area of statistics. Building on the decision of the Statistical Commission, we encourage all countries to test, experiment and work together to establish best practices in the area of ecosystem accounting, and to further develop and enhance this framework.

United Nations

European Commission

Food and Agriculture Organization of the United Nations

OECD

Organisation for Economic Co-operation and Development

World Bank Group

Preface

1. Ecosystem accounting is a relatively new and emerging field dealing with the integration of complex biophysical data, use of those data to track changes in ecosystems and linkage of the changes to economic and other human activity. Considering the increasing demand for statistics on ecosystems within analytical and policy frameworks on environmental sustainability, human well-being and economic growth and development, advancing this emerging field of statistics has become increasingly urgent.

2. Experience exists in related areas of statistics such as land-cover and land-use statistics but the integration of these and related statistics into an accounting framework is new. There is also considerable existing expertise in the fields of ecosystem science and economics that is relevant, but again, it is the integration of these different areas of expertise within the proposed ecosystem accounting approach that is new.

3. At its forty-fourth session in 2013, the United Nations Statistical Commission welcomed the System of Environmental-Economic Accounting 2012—Experimental Ecosystem Accounting (SEEA Experimental Ecosystem Accounting) as representing an important first step in the development of a statistical framework for ecosystem accounting; and encouraged the use of SEEA Experimental Ecosystem Accounting by international and regional agencies and countries wishing to test and experiment in this new area of statistics.[1] In taking these steps, the Statistical Commission recognized the growing policy demand for information about ecosystems and the linkages to economic and other human activity.

4. SEEA Experimental Ecosystem Accounting offers a synthesis of the current knowledge in this area and serves as a platform for the development of ecosystem accounting at national and subnational levels. It provides a set of terms, concepts, accounting principles and classifications; and an integrated accounting structure of ecosystem services and ecosystem condition in both physical and monetary terms. In SEEA Experimental Ecosystem Accounting, it is recognized that spatial areas must form the basic focus for measurement.

5. The framework and associated accounts described in SEEA Experimental Ecosystem Accounting complement the conceptual framework and accounts presented in the international statistical standard for environmental-economic accounting, the System of Environmental-Economic Accounting 2012—Central Framework (SEEA Central Framework). This complementarity is based on four main features: (a) the use of the same accounting principles, accounting structures and relevant classifications, thus allowing the measurement of ecosystem condition and ecosystem services in conjunction with each other and in conjunction with standard measures of economic activity; (b) the adoption of a systems view that focuses on the relationships among the individual environmental assets (e.g., timber, water and soil resources) that are defined in the SEEA Central Framework; (c) the capacity to assess the environmental impacts of economic and other human activity to complement the measurement of environmental pressures, which is a general focus of accounts in the SEEA Central Framework; and (d) the use of a rigorous spatially based approach to measurement

1 See *Official Records of the Economic and Social Council, 2013, Supplement No. 4* (E/2013/24), chap. I, sect. C, decision 44/104, para. (e).

which complements the generally national-level focus of accounting in the SEEA Central Framework.

6. In this context, the development of ecosystem accounting should be envisaged as an enhancement within the broad SEEA framework rather than as an alternative or competing approach to environmental-economic accounting. Together, the SEEA Central Framework and SEEA Experimental Ecosystem Accounting have the potential to comprehensively capture the relationship between the environment and economic and other human activity.

7. As SEEA Experimental Ecosystem Accounting is not an international standard, countries are neither expected nor required to implement ecosystem accounting within the framework of their set of official statistics. At the same time, in line with the encouragement of the Statistical Commission, it is anticipated that countries will test and experiment with ecosystem accounting, or with specific components thereof, in the coming years.

8. To support such efforts and to provide ongoing momentum for work in this area at an international level, a research agenda for ecosystem accounting has been proposed. The research agenda recognizes that while important steps have been taken, a number of conceptual and practical issues remain to be addressed before more definitive guidelines can be provided. It also recognizes that the advancement of the research agenda as well as the testing of SEEA Experimental Ecosystem Accounting will require engagement across disciplines and organizations.

9. There is broad interest in ecosystem accounting beyond the statistical community and there are many projects and initiatives at corporate, local, subnational, national and international levels that entail activities related to ecosystem accounting. In broad terms, the ecosystem accounting framework described in SEEA Experimental Ecosystem Accounting has the capacity to establish connections with and support these various initiatives. Consequently, it is important that countries that undertake testing and research in this area seek to obtain input from and build relationships with these other initiatives.

10. SEEA Experimental Ecosystem Accounting was prepared under the auspices of the United Nations Committee of Experts on Environmental-Economic Accounting (UNCEEA), as mandated by the Statistical Commission at its thirty-eighth session in 2007. The Committee of Experts is a governing body comprising senior representatives from national statistical offices and international organizations. It is chaired by a representative of one of the country members of the Committee. The United Nations Statistics Division serves as the Committee secretariat. Regular oversight of the project was provided by the Bureau of the Committee.

11. The coordination of the technical input into the SEEA Experimental Ecosystem Accounting process was achieved through a series of meetings of experts from a range of disciplines, including economics, ecology and the physical sciences, geography, national accounts and official statistics. These experts provided insights into the current state of knowledge, the measurement challenges and the potential ways forward. Members of the London Group on Environmental Accounting, who had led the technical development of the SEEA Central Framework, were also able to contribute by ensuring that appropriate connections were made between the two instruments.

12. The contributions of these meetings of experts and of the members of the London Group were brought together by the Editor and the Editorial Board of SEEA Experimental Ecosystem Accounting. The Editorial Board, established in March 2012, provided the Editor who drafted the text with technical advice and direction. Initial draft chapters were discussed by the Editorial Board, at a meeting of experts in May 2012, and by the London Group in October 2012. In November 2012, broad consultations were held on revised draft chapters. A final draft reflecting the feedback provided was submitted to the Statistical Commission in February 2013 for its consideration.

Acknowledgements

Background

1. SEEA Experimental Ecosystem Accounting is the outcome of a process notable for its transparency and the wide involvement of the international statistical community, economists, scientists, policymakers and others. The process comprised five steps:

(a) Identifying and securing agreement on the issues to be considered in the drafting of SEEA Experimental Ecosystem Accounting;

(b) Research on those issues and presentation of proposals for addressing them;

(c) Consideration by experts of the issues and proposals and agreement on a provisional draft text;

(d) Consultation with countries and experts on specific issues as well as complete chapters, incorporation of comments elicited through the consultation process, and preparation of a final draft of SEEA Experimental Ecosystem Accounting;

(e) Presentation of the draft to the Statistical Commission at its forty-fourth session, held in February and March 2013. In its report on the forty-fourth session, the commission "[w]elcomed SEEA Experimental Ecosystem Accounting as an important first step in the development of a statistical framework for ecosystem accounting, and encouraged its use by international and regional agencies and countries wishing to test and experiment in this new area of statistics".[2]

The United Nations Committee of Experts on Environmental-Economic Accounting (UNCEEA) and its Bureau

2. The process of drafting SEEA Experimental Ecosystem Accounting involved the United Nations Committee of Experts on Environmental-Economic Accounting; other international, regional and nongovernmental organizations; project staff; agencies responsible for compiling official statistics in many countries; city groups; other expert groups; and individual experts in economics, ecosystem science and related fields from multiple regions of the world. As could be expected of the product of such a sustained and involved process, SEEA Experimental Ecosystem Accounting encompasses many and diverse contributions.

3. The Statistical Commission established the Committee of Experts at its thirty-sixth session in March 2005 with the mandate, among others, to oversee and manage the revision of the SEEA.[3] The Committee of Experts comprises senior representatives of national statistical offices and international agencies.

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2 See *Official Records of the Economic and Social Council, 2013, Supplement No. 4* (E/2013/24), chap. I, sect. C, decision 44/104, para. (e).

3 *Official Records of the Economic and Social Council, 2005, Supplement No. 4* (E/2005/24), chap. V, para. 7.

4. The Bureau of the Committee of Experts, whose representatives are elected from among the members, acts under authority delegated by the Committee. The Bureau managed and coordinated the preparation of SEEA Experimental Ecosystem Accounting

5. The Committee of Experts and its Bureau were chaired by Peter Harper (Australia, 2009-2013).

6. The following persons served as members of the Bureau of the Committee of Experts: Peter Harper (Australia), 2009-2013; Karen Wilson (Canada), 2009-2011; Art Ridgeway (Canada), 2012-2013; Peter van de Ven (Netherlands), 2009-2011; Geert Bruinooge (Netherlands), 2012-2013; Olav Ljones (Norway), Chair, Oslo Group on Energy Statistics, 2009-2013; Joe de Beer (South Africa), 2010-2013; Pietro Gennari (Food and Agriculture Organization of the United Nations), 2011-2013; Alessandra Alfieri, Paul Cheung, Ivo Havinga and Eszter Horvath (UNSD), 2009-2013; Mark de Haan (Chair, London Group on Environmental Accounting), 2009-2012; Pedro Diaz (Eurostat), 2009-2013; Glenn-Marie Lange (World Bank), 2010-2013; Peter van de Ven (OECD), 2013; and Joe St Lawrence (Chair, London Group on Environmental Accounting), 2013.

7. The staff of the Economic Statistics Branch of the United Nations Statistics Division under the overall supervision of Ivo Havinga (UNSD) and with the assistance of Alessandra Alfieri (UNSD) provided secretariat services to the Bureau of the Committee of Experts.

8. The following country representatives served as members of the Committee of Experts: Peter Harper and Gemma van Halderen (Australia); Luiz Paulo Souto Fortes, Wadih Joao Scandar Neto and Eduardo Nunes (Brazil); Martin Lemire, Art Ridgeway and Robert Smith (Canada); Huaju Li and Yixuan Wang (China); Luz Amparo Castro, Monica Rodriguez Diaz, Carlos Eduarte Sepulveda Rico and Luz Dary Yepes Rubiano (Colombia); Ole Gravgård Pedersen, Bent Thage and Kirsten Wismer (Denmark); Miguel Jimenez Cornielle, Roberto Blondet Hernandez, Olga Luciano Lopez and Olga Diaz Mora (Dominican Republic); Leo Kolttola (Finland); Michael Kuhn and Karl Schoer (Germany); Ramesh Chand Aggarwal, Jogeswar Dash and Shri V. Parameswaran (India); Kecuk Suhariyanito and Slamet Sutomo (Indonesia); Cesare Costantino (Italy); Geert Bruinooge, Mark de Haan and Peter van de Ven (Netherlands); Torstein Bye and Olav Ljones (Norway); Khalaf Al-Sulaimani (Oman); Estrella Domingo and Raymundo Talento (Philippines); Sergey Egorenko, Igor Kharito and Andrey Tatarinov (Russian Federation); Joe de Beer and Anemé Malan (South Africa); Inger Eklund and Viveka Palm (Sweden); Rocky Harris (United Kingdom of Great Britain and Northern Ireland) and Dennis Fixler (United States of America).

9. The following representatives of international organizations served as members of the Committee of Experts: Lidia Bratanova (ECE), Salvador Marconi and Kristina Taboulchanas (ECLAC); Joel Jere (ESCAP); Wafa Aboul Hosn (ESCWA); Jean-Louis Weber (European Environment Agency); Pedro Díaz Muñoz and Pieter Everaers (Eurostat); Pietro Gennari (FAO); Manik Shrestha (IMF); Myriam Linster and Peter van de Ven (OECD); Linda Ghanimé, Maria Netto and Veerle van de Weerd (UNDP); Kathleen Abdalla, Tariq Banuri, Matthias Bruckner, Jean-Michel Chéné, Manuel Dengo, Liisa-Maija Harju, David O'Connor and Mary Pat Silveira (Division of Sustainable Development of the Department of Social and Economic Affairs of the United Nations Secretariat); Hussein Abaza, Derek Eaton, Maaike Jansen, Fulai Sheng, Guido Sonnemann and Jaap van Woerden (UNEP); Alessandra Alfieri, Ivo Havinga and Eszter Horvath (UNSD); Kirk Hamilton, Barbro Elise Hexeberg, Glenn-Marie Lange and Marian S. delos Angeles (World Bank).

10. The following participated as observers in the Committee of Experts: Peter Cosier (Wentworth Group of Concerned Scientists, Australia) and Markus Lehman (Secretariat of the Convention on Biological Diversity).

11. Experts in ecosystem accounting from international organizations who regularly provided substantive contributions were: Brian Newson and Anton Steurer (Eurostat); Jock Martin and Jean Louis Webber (European Environment Agency); Alessandra Alfieri and Ivo Havinga (UNSD); and Glenn-Marie Lange (World Bank)

12. Other staff members of international organizations who contributed substantively were: Julian Chow, Daniel Clarke, Magdolna Csizmadia, Anthony Dvarskas, Ricardo Martinez-Lagunes, Leila Rohd-Thomsen and Sokol Vako (UNSD).

13. Michael Brodsky of the Department for General Assembly Affairs and Conference Management copy-edited the original manuscript.

14. The United Nations Statistics Division developed and maintained the project website (http://unstats.un.org/unsd/envaccounting/default.asp), which provides more information on the contributions summarized here.

Editorial Board

15. The SEEA Experimental Ecosystem Accounting Editorial Board, which provided technical guidance on the drafting of the text and expert advice on the resolution of technical issues, consisted of: Carl Obst (SEEA Editor, Chair), Michael Vardon (Australian Bureau of Statistics), Warwick McDonald (Bureau of Meteorology, Australia), Michael Bordt (previously with Statistics Canada), Bram Edens (Central Bureau of Statistics, Netherlands), Per Arild Garnåsjordet (Statistics Norway), Lars Hein (Wageningen University, Netherlands), Jawed Khan (Office for National Statistics, United Kingdom of Great Britain and Northern Ireland), Jock Martin and Jean-Louis Weber (European Environment Agency), Anton Steurer (Eurostat) and Glenn-Marie Lange (World Bank). Alessandra Alfieri (UNSD) provided secretariat services to the Editorial Board.

Expert group meetings

16. Four expert group meetings took place in 2011 and 2012 to discuss issues related to ecosystem accounting. The meetings were held in March 2011 in Washington, D.C., hosted by the World Bank; in May 2011 in Copenhagen, hosted by the European Environment Agency; in December 2011 in London, hosted by the Office for National Statistics and the Department for Environment, Food and Rural Affairs of the United Kingdom of Great Britain and Northern Ireland; and in May 2012 in Melbourne, Australia, hosted by the Australian Bureau of Statistics, the Australian Bureau of Meteorology and the Department of Sustainability and Environment, Victoria.

17. The following experts participated in the expert group meetings: Buyung Airlangga, Judith Ajani, Alessandra Alfieri, Olivier Arino, Suzi Bond, Michael Bordt, Jim Boyd, Daniel Clarke, Peter Comisari, Steven Cork, Peter Cosier, Antonio Di Gregorio, Bram Edens, Mark Eigenrram, Per Arild Garnåsjordet, Haripriya Gundimeda, Roy Haines-Young, Peter Harper, Rocky Harris, Julie Hass, Andreas Hauser, Ivo Havinga, Lars Hein, Akira Hibiki, Emil Ivanov, Jawed Khan, Thomas Koellner, Leo Kottola, Pushpam Kumar, Glenn-Marie Lange, Markus Lehmann, Myriam Linster, Donna Livesey, Olav Ljones, Jock Martin, Simone Maynard, Jane McDonald, Warwick McDonald, Guillaume Mordant, Richard Mount, Michael Nagy, Paulo Nunes, Carl Obst, Marc Paganini, Alessardra Palmieri, Michele Pittini, Bradley Reed, Jean-Pierre Reveret, Taylor Rickets, Gerbert Roerink, Elisabeth Schwaiger, Burkhard Schweppe-Kraft, David Simpson, William Sonntag, Anton Steurer, Gary Stoneham, S. Suresh Kumar, Stave Svein Erik, Etjih Tasriah, Ben ten Brink, Patrik ten Brink, Stephanie Uhde, Bart Ullstein, Michael Vardon and Jean-Louis Weber.

International seminar

18. An international seminar entitled "Towards linking ecosystems and ecosystem services to economic and human activity" was held in New York in November 2012. The seminar was jointly organized by UNSD, the United Nations Development Programme (UNDP), the United Nations Environmental Programme (UNEP), the World Bank and the European Environment Agency.

19. The following experts participated in the international seminar: Mark Eigenraam, Peter Harper and Bruce Hockman (Australia), Golam Kamal (Bangladesh), Wadih Neto (Brazil), Céo Gaudet and Arthur Ridgeway (Canada), Huaju Li (China), Mónica Madrid (Colombia), Awatef Hussein Abou Gendy (Egypt), Leena Storgårds (Finland), Guillaume Mordant (France), Harald Lossack (Germany), James Mathew (India), Laksmi Dhewanthi, Lien Rosalina, Novrizal Tahar and Dewi Sri Takarini (Indonesia), Mathew Omondi Oduor (Kenya), Francisco Guillen Martin (Mexico), Lamia Laabar (Morocco), Geert Bruinooge and Ben ten Brink (Netherlands), Per Arild Garnåsjordet (Norway), Mohammed Al-Marzouqi and Michael Nagy (Qatar), Eliana Quispe (Peru), Candido Astrologo (Philippines), Andrey Tatarinov (Russian Federation), Tracey Lyn Cumming (South Africa), Alexander Girvan (Trinidad and Tobago), Catherine Connolly (United Kingdom of Great Britain and Northern Ireland), Dennis Fixler and Steve Landefeld (United States of America), Nguyen Tuan Anh (Viet Nam), Judith Ajani (Australian National University), Braulio Ferreira de Souza Dias (Secretariat of the Convention on Biological Diversity), Geoffrey Heal (Columbia University), Jana Tafi (consultant), Jean-Louis Weber (European Environment Agency), Pedro Diaz, Brian Newson and Walter Radermacher (Eurostat), Gary Jones (FAO), Thomas Lovejoy (Heinz Center), Marco Cangiano (New York University), Shamshad Akhtar (Department of Economic and Social Affairs of the United Nations Secretariat), Charles McNeill and Tim Scott (UNDP), Robert Vos (Development Policy and Analysis Division of the Department of Economic and Social Affairs of the United Nations Secretariat), Matthias Bruckner, Keneti Faulalo and David O'Connor (Division for Sustainable Department of the Department of Economic and Social Affairs of the United Nations Secretariat), Rodney Smith (University of Minnesota), Alessandra Alfieri, Ivo Havinga, Eszter Horvath and Carl Obst (UNSD) and Glenn-Marie Lange (World Bank).

London Group on Environmental Accounting

20. The London Group on Environmental Accounting discussed issues related to SEEA Experimental Ecosystem Accounting at its eighteenth meeting held in October 2012 in Ottawa, and hosted by Statistics Canada. The London Group was chaired by Sjoerd Schenau on behalf of Mark de Haan (Statistics Netherlands).

21. The following people participated in the eighteenth meeting of the London Group: Alessandra Alfieri, Michael Bordt, Julian Chow, Raúl Figueroa Díaz, Bram Edens, Mark Eigenraam, Per Arild Garnåsjordet, Kyle Gracey, Ryan Greenaway-McGrevy, Rocky Harris, Julie Hass, Gary Jones, Jawed Khan, Suresh Kumar Sukumarapillai, Glenn-Marie Lange, Warwick McDonald, Richard Mount, Jukka Muukkonen, Urvashi Narain, Frédéric Nauroy, Carl Obst, Thomas Olsen, Viveka Palm, Masahiro Sato, Sjoerd Schenau, Joe St. Lawrence, Anton Steurer, Stéphanie Uhde, Michael Vardon and Jean-Louis Weber.

Other groups of experts

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Country contributions

23. National statistical offices, ministries responsible for the environment and other national agencies made significant in-kind contributions to the drafting of SEEA Experimental Ecosystem Accounting. Over 55 countries and international organizations submitted comments during the broad consultation on the draft of the document held from November 2012 to January 2013. Heads of the national statistical offices were involved through their participation in the Statistical Commission.

24. Last but not least, a number of national and international agencies supported the project through financial contributions. Australia and Eurostat were major financial contributors to the project.

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List of abbreviations and acronyms

BSU	basic spatial unit
CBD	Convention on Biological Diversity
CFC	consumption of fixed capital
CICES	Common International Classification of Ecosystem Services
CO_2	carbon dioxide
COP	Conference of the Parties
CPI	consumer price index
EAU	ecosystem accounting unit
ECE	Economic Commission for Europe
ECLAC	Economic Commission for Latin America and the Caribbean
EEZ	exclusive economic zone
EGSS	environmental goods and services sector
EPEA	environmental protection expenditure account
ES	ecosystem services
ESCAP	Economic and Social Commission for Asia and the Pacific
ESCWA	Economic and Social Commission for Western Asia
FAO	Food and Agriculture Organization of the United Nations
FDES	Framework for the Development of Environment Statistics
GDP	gross domestic product
GIS	geographic information systems
IMF	International Monetary Fund
IUCN	International Union for Conservation of Nature
kg	kilogram
km	kilometre
LAI	leaf area index
LCCS 3	Land Cover Classification System, version 3

LCEU	land-cover/ecosystem functional unit
m	metre
MA	Millennium Ecosystem Assessment
NPISH	non-profit institutions serving households
NPV	net present value
NSO	national statistical office
NTFP	non-timber forest product
OECD	Organisation for Economic Co-operation and Development
PES	payments for ecosystem services
PM	particulate matter
SEEA	System of Environmental-Economic Accounting
SNA	System of National Accounts
TEEB	The Economics of Ecosystems and Biodiversity
TEV	total economic value
UK	United Kingdom of Great Britain and Northern Ireland
UN	United Nations
UNCEEA	United Nations Committee of Experts on Environmental-Economic Accounting
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations Collaboration Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
UNSC	United Nations Statistical Commission

Chapter I

Introduction

1.1 What is the System of Environmental-Economic Accounting 2012—Experimental Ecosystem Accounting (SEEA Experimental Ecosystem Accounting)?

1.1 Ecosystem accounting is a coherent and integrated approach to the assessment of the environment through the measurement of ecosystems, and measurement of the flows of services from ecosystems into economic and other human activity. The scale on which the accounting may be conducted varies: the ecosystems measured may range from specific land cover type areas, such as forests, to larger integrated areas, such as river basins, and may include areas considered to be relatively natural and those that are heavily affected by human activity, such as agricultural areas.

1.2 Ecosystem accounting goes beyond other approaches to ecosystem analysis and assessment through its explicit linking of ecosystems to economic and other human activity. The links are forged through the services provided by ecosystems and the impacts that economic and other human activity may have on ecosystems and their future capacity. While ecosystem accounting does consider ecosystems and the economy to be different systems, they are analysed jointly so as to reflect the fundamental connections between them. The use of an accounting framework enables the stock of ecosystems—*ecosystem assets*—and flows from ecosystems—*ecosystem services*—to be defined in relation to each other and to a range of other environmental, economic and social information.

1.3 A prime motivation for ecosystem accounting is an awareness of the fact that the separate analyses of ecosystems and the economy do not encompass the vital relationship between people and the environment in which we live. The standard approaches to the measurement of the economy focus largely on economic and other human activity, as reflected in the activity of markets. Ecosystem accounting aims to shed light on the non-market activity associated with ecosystems and to integrate the information obtained with relevant market-related data. It is anticipated that individual and societal decisions concerning the use of the environment will be better informed through the use of information sets that are developed based on a recognition of the relationship between ecosystems and economic and other human activity.

1.4 In this broad context, the System of Environmental-Economic Accounting 2012—Experimental Ecosystem Accounting (SEEA Experimental Ecosystem Accounting) constitutes an integrated statistical framework for organizing biophysical data, measuring ecosystem services, tracking changes in ecosystem assets and linking this information to economic and other human activity. The perspective of SEEA Experimental Ecosystem Accounting is complementary to that of the accounting approaches described in the System of

Environmental-Economic Accounting 2012—Central Framework (SEEA Central Framework), although it does not have the status of an international statistical standard.

1.5 SEEA Experimental Ecosystem Accounting is based on a synthesis of measurement concepts derived from a number of disciplines. It is intended for use in encouraging and supporting work on ecosystem accounting and in facilitating the exchange of experiences related to the testing of its various components. Without a synthesis of relevant terms and concepts, the ability to communicate effectively across multidisciplinary programmes of work in this area will be significantly diminished. Indeed, those working in the various disciplines are well aware that there is a need for further harmonization with regard to terminology and definitions. The coherent and integrated approach of SEEA Experimental Ecosystem Accounting should be particularly useful in this regard.

1.6 The style of SEEA Experimental Ecosystem Accounting reflects the fact that ecosystem accounting is a relatively new and emerging field of measurement and hence work in this field is considered experimental. Nonetheless, ecosystem accounting builds on findings in well-established disciplines, including ecosystem science, economics, and official statistics, especially national accounting and the related field of environmental-economic accounting.

1.7 Ecosystem accounting as presented in the present publication encompasses measurement of the contribution of ecosystems to standard measures of economic activity, such as gross domestic product (GDP) and national income, and assessment of the role played by ecosystems in providing a range of other benefits to human well-being that are commonly unpriced and not considered in national-level economic reporting and analysis. The strength of ecosystem accounting is its use of the same broad, logical approach that is utilized in the standard measurement of the economy, which can then be applied in the analysis of the environment.

1.8 Expansion beyond standard approaches to economic and ecosystem measurement requires the involvement of multiple disciplines. The development of an ecosystem accounting framework as described here reflects such a multidisciplinary effort. The ongoing work designed to test and establish the relevant statistical infrastructure, to compile and organize relevant information, and to incorporate more extensive information sets into decision-making will continue to require engagement across disciplines and organizations.

1.9 Accounting for ecosystems in physical (i.e., non-monetary) terms[4] is a key feature of SEEA Experimental Ecosystem Accounting. There is a significant amount of information in physical terms that can be organized within an accounting framework to support analysis and monitoring. The organization of physical information is the focus of chapters III and IV. Chapters V and VI describe approaches to accounting for ecosystems in monetary terms, which entail the introduction of additional issues relating to valuation. In this regard, measurement in monetary terms for ecosystem accounting purposes is generally dependent on the availability of information in physical terms, since there are few observable market values for ecosystems and their services.

1.10 This publication provides an integrated framework for ecosystem accounting. Still, in a number of areas, it is clear that further advancement in terms of concepts and theory is required; and in all areas, the development and testing of measurement methods is needed. A research agenda for ecosystem accounting is described in the annex. It is important that on-the-ground experience be gained through the testing of the accounting framework outlined in SEEA Experimental Ecosystem Accounting. To this end, it is expected that the concepts

4 The phrase “physical terms” is used generically to refer to all measures in non-monetary terms. In some cases, the measures refer to material stocks and flows (e.g., plants, animals and water) and, in others, to non-material flows such as the amenity services derived from landscapes.

and terminology described will support testing efforts and facilitate the sharing of experiences in ecosystem accounting.

1.11 In due course, this accounting framework will be reviewed and updated in light of country experience and conceptual advances, so as to further facilitate collaboration across disciplines and support countries in compiling and using ecosystem accounts.

Motivation for SEEA Experimental Ecosystem Accounting

1.12 The development of SEEA Experimental Ecosystem Accounting reflects the recognition that measurement of the environmental-economic relationship should encompass the understanding that the environment is a system capable of self-regeneration and degradation. This systems perspective, embodied in the breadth of research on biodiversity, ecosystems and the link to human activity, is one that complements the perspectives concerning the measurement of the environment and the economy described in the SEEA Central Framework and the System of National Accounts (SNA).

1.13 Through the adoption of a systems perspective on environmental assets, information organized within the context of SEEA Experimental Ecosystem Accounting is able to provide an indication of impacts (both positive and negative) of economic and other human activity on the environment and can highlight the potential trade-offs among the different combinations of ecosystem services that are generated from alternative uses of ecosystems.

1.14 With its potential to inform on environmental impacts and trade-offs in ecosystem use, SEEA Experimental Ecosystem Accounting provides a framework for responding to the growing demands for information in policy areas such as sustainable development, resource use and land management. While the SEEA Central Framework and the SNA can inform on these issues from an economic perspective, the complementary perspective provided by SEEA Experimental Ecosystem Accounting represents an important addition.

Development of SEEA Experimental Ecosystem Accounting

1.15 SEEA Experimental Ecosystem Accounting has been developed within the broader process of revising the SEEA 2003—a process initiated by the United Nations Statistical Commission (UNSC) in 2007. The primary objective of the SEEA revision process was the establishment of a statistical standard for environmental-economic accounting. At its forty-third session, held from 28 February to 2 March 2012, the Statistical Commission adopted the SEEA Central Framework as the international statistical standard for environmental-economic accounting.[5] The SEEA Central Framework is a multipurpose, conceptual tool for describing interactions between the economy and the environment, and the stocks and changes in stocks of environmental assets. It is so structured as to enable source data to be compared and contrasted, aggregates and indicators to be derived, and trends to be analysed across a broad spectrum of environmental and economic issues.

1.16 The SEEA revision process also involved the drafting of two additional publications, one covering those topics on which consensus could not be reached but which were still highly policy-relevant, and the other focused on applications and extensions of the SEEA Central Framework. During the process of drafting the SEEA Central Framework, it became clear that those topics within the SEEA 2003 that could not be advanced and agreed to at the level of creation of an internationally agreed standard related primarily to accounting for ecosystems and their degradation.

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5 See *Official Records of the Economic and Social Council, 2012, Supplement No. 4* (E/2012/24), chap. I, sect. B, decision 43/105, para. (c).

1.17 Recognizing the increasing relevance of and interest in the measurement of ecosystems, their degradation, and the flow of ecosystem services, the Statistical Commission supported the development of SEEA Experimental Ecosystem Accounting, with the process managed by the United Nations Committee of Experts on Environmental-Economic Accounting. As noted above, SEEA Experimental Ecosystem Accounting does not constitute an international statistical standard, providing instead an accounting framework for multidisciplinary research and testing on ecosystems and their relationship to economic and other human activity.

Relationship to the SEEA Central Framework

1.18 Like the SEEA Central Framework, SEEA Experimental Ecosystem Accounting describes accounting in physical (i.e., non-monetary) and monetary terms. The extension of the SEEA to encompass accounting of stocks and flows in physical terms is significant and requires the integration of scientific information within standard economic accounting frameworks. A key feature of the SEEA lies in the fact that the organization of information in physical terms facilitates comparison with economic data even without monetary valuation and thus contributes to analysis from both economic and environmental perspectives.

1.19 SEEA Experimental Ecosystem Accounting has a distinct perspective on the measurement of environmental assets. In both the SEEA Central Framework and SEEA Experimental Ecosystem Accounting, environmental assets are defined broadly as "the naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity".[6] However, for measurement purposes, environmental assets are considered from two complementary perspectives.[7] In the SEEA Central Framework, the perspective for measurement purposes is on "individual" environmental assets, such as timber resources, land, mineral and energy resources, and water resources.

1.20 In contrast, in SEEA Experimental Ecosystem Accounting, the perspective is on ecosystems. This approach assesses how different individual environmental assets interact as part of natural processes within a spatial area to provide a range of services for economic and other human activity.[8] Ecosystem assets are thus environmental assets as viewed from a systems perspective.

1.21 Since not all individual environmental assets function within ecosystems, notably mineral and energy resources, a complete accounting for environmental assets requires both the SEEA Central Framework and SEEA Experimental Ecosystem Accounting. Further, as described in chapter IV, the practice of measuring ecosystem condition is likely to benefit from the use of information contained in asset accounts for individual resources, such as water and timber resources, which are described in the SEEA Central Framework.

Relationship to the System of National Accounts (SNA)

1.22 Like the accounting approach presented in the SEEA Central Framework, ecosystem accounting as set out in SEEA Experimental Ecosystem Accounting has its genesis in the System of National Accounts (SNA). The SNA, which is the international statistical standard for the compilation of national accounts, incorporates many of the most commonly consid-

6 SEEA Central Framework, para. 2.17.

7 Ibid., paras. 2.16-2.23.

8 This dual perspective on environmental assets is introduced in the SEEA Central Framework, paras. 2.17-2.22.

ered economic measures, such as gross domestic product (GDP), household consumption and saving, investment (capital formation), profits (gross operating surplus), exports and imports, and measures relating to assets and liabilities. The first SNA, entitled *A System of National Accounts and Supporting Tables*, was finalized in 1953 (United Nations, 1953) and the most recent version (European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, United Nations and World Bank, 2009) was adopted in 2008.

1.23 One motivation for the development of the SEEA was the recognition that the SNA does not provide an explicit or comprehensive accounting for environmental stocks and flows that are relevant in the context of a more complete assessment of economic activity. In this context, SEEA Experimental Ecosystem Accounting represents one approach to extending the SNA.

1.24 In order to provide such an extension, SEEA Experimental Ecosystem Accounting retains many of the core accounting concepts and approaches that have developed over time within an SNA context. The scope of economic activity, definitions and classifications of economic units, the types of accounts and principles of valuation are all aligned between the two documents.

1.25 At the same time, SEEA Experimental Ecosystem Accounting extends some SNA measurement boundaries. First, a broader set of services are recognized as contributing to human well-being. This is achieved by accounting for ecosystem services beyond those that provide input into the production of goods and services that are traditionally within scope of the SNA production boundary. Second, the asset boundary is extended compared with that of the SNA through (a) using the whole biophysical environment as a starting point (as in the SEEA Central Framework) and (b) recognizing a broader set of services derived from ecosystem assets.

1.26 In making these changes, it has been necessary to apply the ecosystem accounting approach within the SNA measurement boundaries as well as beyond them so as to provide a consistent accounting treatment. Hence, understanding and making explicit relevant stocks and flows that are already reflected within the SNA constitute an important component of ecosystem accounting.

1.27 A further extension relative to the SNA is achieved through the focus on smaller spatial areas than those commonly considered in national accounting. The SNA defines its geographical scope with reference to a country's economic territory. For ecosystem accounting purposes, the economic territory is disaggregated into spatial units following a model described in section 2.3.

The role of valuation in SEEA Experimental Ecosystem Accounting

1.28 Valuation in SEEA Experimental Ecosystem Accounting is considered through the estimation of relevant stocks and flows in monetary terms. Estimation in monetary terms is required in order to augment the accounts of the SNA with ecosystem accounting information, for example, in the compilation of extended measures of wealth or augmented sequences of accounts.[9] Estimation in monetary terms may be sought for other reasons, including the assessment of alternative policy scenarios and the estimation of the social benefits generated by ecosystem services.

9 It is noted that ecosystem accounting information in physical terms may be combined with economic data in monetary terms through so-called combined presentations (see chap. VI).

1.29 While measures in monetary terms may be important for some purposes, there is a significant advantage in applying accounting approaches to the organization of information and the compilation of accounts in physical terms, as shown in the SEEA Central Framework.[10] Consequently, the potential of ecosystem accounting as described in SEEA Experimental Ecosystem Accounting is not restricted by a requirement to value ecosystem assets and ecosystem services in monetary terms or by the desire to derive degradation-adjusted measures of national income.

1.30 The broad scope of ecosystem accounting recognizes that the assessment of the relationship between ecosystems and economic and other human activity can be informed by a wide range of data, in both physical and monetary terms, presented in a coherent and integrated manner.

1.2 Policy relevance of ecosystem accounting

1.31 The broad and integrated nature of SEEA Experimental Ecosystem Accounting and its underlying accounting approach are of direct relevance to the organization of data for assessing changes in ecosystems and the services they provide, and placing the relevant information in a socioeconomic context.

1.32 As such, the policy relevance of ecosystem accounting to economic and environmental assessments is real and very broad. It stems from the understanding that policy responses should recognize the fundamental connections between economic activity and ecosystems. There are thus strong connections to programmes of work on broader measures of progress and sustainable development. Increasingly, policy in different areas of public concern, including land and resource management, is being considered in a more integrated and multidisciplinary fashion, with economic, social and environmental factors being assessed jointly in determining appropriate policy responses.

1.33 A general motivation for the development of ecosystem accounting is its capacity to provide information needed for tracking changes in ecosystems and linking those changes to economic and other human activity. A particular motivation for the development of ecosystem accounting is the concern that economic and other human activity is leading to an overall degradation of ecosystems and that consequently ecosystems have a reduced capacity to provide the services on which people depend.

1.34 This phenomenon is recognized in several global policy processes, most notably the ongoing work pursuant to the United Nations Conference on Sustainable Development and the outcomes of the recent meetings of the Conference of the Parties to the Convention on Biological Diversity. In addition, global initiatives such as the World Bank Wealth Accounting and the Valuation of Ecosystem Services (WAVES) project and The Economics of Ecosystems and Biodiversity (TEEB) are among key users of ecosystem accounting frameworks. Together, these various drivers provide a motivation for experimentation in this area of measurement.

1.35 In combination with the accounts of the SEEA Central Framework, ecosystem accounting information on the extent to which ecosystems are impacted by economic and other human activity can be used to evaluate a number of policy issues, including: the potential for adopting alternative patterns of production, consumption and accumulation; the effect of using alternative sources of energy and other resources and the extent of decoupling from

10 The SEEA Central Framework presents physical accounts for flows of energy, water and various residual flows and also describes accounting for stocks of individual environmental assets in physical terms.

economic growth; the effectiveness of resources spent to restore and enhance ecosystems: and more generally, the trade-offs between the different baskets of ecosystem services derived from alternative uses of ecosystems.

1.36 The potential for assessing trade-offs among baskets of ecosystem services is likely to lead to a particularly powerful application of the ecosystem accounting framework. This potential arises from (a) a broad scope, which includes ecosystem services that contribute to current measures of economic activity together with other ecosystem services that are excluded from their scope, (b) the connections in the framework made between ecosystem services and changes in the ecosystems themselves (e.g., due to ecosystem degradation) and (c) the links between the ecosystem accounting framework and the standard measures of economic activity presented in the SNA.

1.37 SEEA Experimental Ecosystem Accounting provides insights into how ecosystems can be conceptualized as a form of "capital", which may then be considered in relation to other measures of capital, including economic, human, social and other environmental capital. Assessment of changes in the quantity and quality of broad measures of capital is generally recognized as important in the assessment of sustainable development and overall human well-being.

1.38 Since ecosystem accounting requires the development of data sets pertaining to specific geospatial areas, it can provide information needed for the assessment of integrated policy responses at that level of detail; for example, in the context of the management of river basins, fisheries, protected areas and agricultural areas.

1.39 For international policy monitoring processes, SEEA Experimental Ecosystem Accounting has the potential to provide a base upon which to build information sets for use in assessing global ecological cycles and the related global economic challenges. Examples in this area relate to carbon and biodiversity. Since stocks and flows of carbon and changes in biodiversity are central to understanding the operation of ecosystems, ecosystem accounting may assist in providing a coherent basis for measurement in these two policy areas.

1.3 Objectives and challenges in ecosystem accounting

Accounting objectives

1.40 As outlined in the previous section, the overarching objective in developing an accounting structure is the integration of environmental and economic information for application to policy discussions. Within this context, the more specific objectives in establishing an accounting structure are:

(a) Organizing information on the environment from a spatial perspective describing, in a coherent manner, linkages between ecosystems and economic and other human activity;

(b) Applying a common, coherent and integrated set of concepts, classifications and terminology, thus providing a platform for the organization of data and research and testing;

(c) Allowing connections to be made to environmental-economic information compiled following the guidelines of the SEEA Central Framework. This should aid in the understanding of (i) the contribution of ecosystem services to economic production, consumption and accumulation, (ii) the attribution of degradation, restoration and enhancement of ecosystems to economic units and (iii) the development of more comprehensive measures of national wealth;

(d) Identifying information gaps and key information requirements.

1.41 In order for the various accounting objectives to be met, there are specific measurement issues that need to be considered. They are discussed in SEEA Experimental Ecosystem Accounting. The conceptual and methodological responses to those issues are at different stages of development. The key requirements are that:

(a) The objects of measurement—ecosystem assets and ecosystem services—be defined in a manner that permits the compilation of robust and meaningful statistics;

(b) Spatial areas for the assessment of ecosystem assets be delineated;

(c) The structure of relevant accounts be outlined, including links to the SEEA Central Framework accounts;

(d) Relevant valuation concepts and techniques be described and placed within the context of SNA valuation principles.

1.42 These objectives and considerations are focused on integration of environmental and economic information. As part of the broader agenda of measuring sustainable development and progress, there is a keen interest in linking this information to other information on the social aspects of development and progress. SEEA Experimental Ecosystem Accounting does not incorporate in its framework measures related to social and human capital that are often set alongside measures of economic and environmental assets. However, there are many opportunities to link various types of social information within the SEEA framework. Examples include the incorporation of information on distribution and access to water, energy and other resources, and relating distribution of incomes to various environmental pressures (e.g., emissions) and impacts. Chapter IV of SEEA Applications and Extensions describes some possibilities for the integration of social information within the SEEA framework. The spatial focus of SEEA Experimental Ecosystem Accounting provides an additional means of considering such integration.

Measurement challenges

1.43 A full articulation of ecosystem accounting will, inevitably, require the use of much detailed data. Although this is a relatively new area of accounting, a large amount of relevant information, particularly data in physical terms, may be available from existing data sources. At the same time, some data issues will need resolution. For example, some of the data may be proxies for the "ideal" measures, and the data are likely to be incompatible initially with each other, and may be dispersed across various organizations. Consequently, a significant amount of work and associated resources will likely be required to organize and integrate the information. In addition, some data required for ecosystem accounting are likely to be missing completely, necessitating additional data collection. The organization and collection of relevant data may be supported through the updated Framework for the Development of Environment Statistics (FDES) which has been revised in conjunction with the revision of the SEEA.

1.44 These measurement challenges do not, however, invalidate the use of accounting frameworks to compile coherent and structured information. Indeed, an important role of an accounting framework is to assist in the identification of data gaps.

1.45 Given that the measurement focus of ecosystem accounting is on spatial areas, a significant opportunity exists to take advantage of emerging geospatial data sets and related analytical techniques.

1.46 Central to success in meeting these various accounting objectives is the involvement of members of a wide range of professional communities, most notably natural scientists, economists, social scientists and official statisticians. While each community has its own perspective, all of them have an important role to play in developing the appropriate accounting framework and in populating that framework with meaningful information.

1.47 The types of agencies and organizations that are likely to be involved include national statistical offices (NSOs); governmental scientific and meteorological agencies; departments of environment, agriculture, forestry and fishing; and governmental geographical and geospatial information agencies. The establishment of appropriate institutional coordination and management arrangements is essential for sustained implementation.

1.48 It is also recognized that ongoing coordination with key policy agencies including ministries of finance, development, planning and environment is essential to ensuring that the outputs from the compilation of ecosystem accounts are relevant to the policy questions and monitoring requirements handled by those agencies.

1.49 Given the new and emerging status of ecosystem accounting, academia has a strong potential to assist in the development and testing of many aspects of the proposed ecosystem accounting framework. Input from academia may be particularly useful in standardizing and accrediting scientific information for use in national-level ecosystem assessments, in articulating the complex linkages between the condition of ecosystem assets and the ecosystem services they generate, and in advancing research on the valuation of ecosystem services and ecosystem assets.

1.50 In practice, all of the data required to comprehensively report on all aspects of ecosystem accounting described here are unlikely to be available in the short term in any country. Consequently, as with the SEEA Central Framework, countries are encouraged to consider which aspects of ecosystem accounting are most relevant in their own context. Stepwise and incremental approaches to ecosystem accounting through the targeting of specific ecosystem assets or types of ecosystem services may be the most practical starting points in many cases.

1.4 The key disciplines in ecosystem accounting

1.51 While ecosystem accounting is a relatively new and emerging field of measurement, it has a strong foundation in ecosystem science, economics and national accounts. Research in these fields continues to deal with the ever-increasing complexity of economic activity and the ever-increasing understanding of the world in which we live. At the same time, some commonly accepted core principles of ecosystem science, economics and national accounts can serve as a basis for ecosystem accounting.

Core principles of ecosystem science

1.52 As stated in article 2, entitled “Use of terms”, of the Convention on Biological Diversity, ecosystems are a “dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit”. The operation of ecosystems involves processes such as the capture of light, energy and carbon through photosynthesis, the transfer of carbon and energy through food webs, and the release of nutrients and carbon through decomposition. Biodiversity affects ecosystem functioning, as do the changes arising from disturbances and succession. The principles of ecosystem science suggest that natural resources management should be conducted at the level of the ecosystem rather than at the level of the individual species.

1.53 Ecosystems contribute to the generation of a variety of goods and services upon which people depend. These contributions are known as ecosystem services. Single ecosystems will usually generate a number of different ecosystem services. In general terms, the capacity of an ecosystem to provide services depends on the area covered (its extent) and the condition (its quality). This capacity is modified both positively and negatively through human behaviour. Commonly, through land-use conversion (e.g., conversion of forests to cropland), certain types of ecosystems are modified or replaced, which leads to the supply of a different basket of ecosystem services.

1.54 Ecosystems are often subject to complex, non-linear dynamics involving negative or positive feedback loops. These complex dynamics include, for example, multiple steady states, irreversible change or stochastic (random) behaviour. Many types of ecosystems, including temperate and tropical forests, rangelands, estuaries and coral reefs, are influenced and often dominated by complex dynamics. Concepts of resilience, thresholds and irreversibilities are thus important considerations for ecosystem accounting.

Core principles of economics

1.55 Economics has developed into a broad field of study covering investigations into all forms of human activities, including industrial activity, the operation of financial markets and the behaviour of consumers. In general terms, economics is the study of the choices that consumers, business managers and government officials make in order to attain their goals, given the scarcity of resources. Concepts relating to production, consumption, the accumulation and ownership of assets, and the influence of prices are central to the study of economics.

1.56 Given the integrated relationship between the economy and ecosystems, many branches of economics may have a direct link to ecosystem accounting and can provide theoretical and practical input. The sub-fields of agricultural economics, natural resource economics, environmental economics and ecological economics are of particular relevance to ecosystem accounting.[11]

1.57 From a policy perspective, issues such as intra- and intergenerational equity and income distributions, potentially irreversible environmental change, the uncertainty of long-term outcomes, and sustainable development—among many others—are common areas of focus for economists.

1.58 Natural resource economics has traditionally focused on optimal extraction of non-renewable and renewable resources from a social perspective. Research is now focused on all types of natural resources–related questions, with a focus on sustainable use of non–renewable and renewable resources. Insight into the sustainability of policies is obtained by applying economic theory to models and findings derived from the natural sciences.

1.59 Environmental economics is largely focused on research on market failures, such as those related to externalities, common property and public goods. Two main approaches to research within environmental economics focus on the establishment of markets and the identification of missing prices.

11 While these distinct sub-fields do exist, it should nevertheless be recognized that the boundaries between them in the context of practical research are often quite fluid.

1.60 Ecological economics aims directly at integrating economic and ecological principles. Ecological economics is a field of research that traverses a number of traditional disciplines and, as such, considers the interdependence and co-evolution of human economies and natural ecosystems over time and space. One of the distinguishing features of ecological economics is its treatment of the economy as a subsystem within the ecosystem; it is consequently concerned with the preservation of the ecosystems on which the economy is dependent.

1.61 From an accounting perspective, economics underpins many relevant concepts including those relating to ecosystem assets and the associated flow of ecosystem services. By using a broad conceptualization of services, economics is able to consider trade-offs between the generation and use of different services in a more comprehensive fashion. Further, by considering the relationship between ecosystem assets and service flows, economics can directly analyse the potential for ecosystems to continue to provide services into the future. Such an analysis involves consideration of the carrying capacity of the environment.

1.62 A number of branches of economics consider the valuation of ecosystem services, most commonly in a welfare context with a view to assessing broader social costs and benefits of different policy options. A broad and expanding set of approaches exist to enable valuation of these often unpriced services.

Core principles of national accounts

1.63 At the heart of national accounting lies the goal of recording, at a national economy-wide level, measures of economic activity and associated stocks and changes in stocks of economic assets. The accounting approaches are described at length in the SNA, which provides the accounting principles underpinning the SEEA Central Framework and SEEA Experimental Ecosystem Accounting.

1.64 National accounting involves the recording of flows relating to production, consumption and accumulation, and stocks of economic assets. Following the SNA, economic activity is defined in terms of the activities of production, consumption and accumulation. Measurement of each of these activities over an accounting period (commonly one year) is undertaken within the constraints of a production boundary which defines the scope of the goods and services considered to have been produced and consumed.[12] Accumulation of these goods and services in the form of economic assets (e.g., through the construction of a house) is recorded in cases where production and consumption are spread out over more than one accounting period. Further, non-produced and financial assets may be accumulated (e.g., through the purchase of land).

1.65 Central to the measurement of economic activity and economic assets is the recognition of economic units, that is, the different legal and social entities that participate in economic activity. At the broadest level, these entities are categorized as enterprises, governments and households. The economy of a given territory is defined by the set of economic units (referred to in the SNA as institutional units) that are resident (i.e., have a centre of economic interest) in that territory.

1.66 The national accounts thus aim to organize and present information on the transactions and other flows between these economic units (including flows between units in different territories) and on the stocks of economic assets owned and used by economic units.

1.67 There are strong similarities between national accounting and the accounting that is undertaken for an individual business. The main distinctions are that national accounting:

12 This boundary also defines the measurement scope for the most widely known national accounts aggregate, gross domestic product (GDP).

(a) requires consideration of the accounting implications for more than one business (thus the recording must be consistent for both parties to a transaction without overlaps or gaps); and (b) operates on a far larger scale in providing information for a country and encompasses a wide variety of types of economic units which play distinct roles in an economy.

Creating linkages between disciplines

1.68 Placing ecosystems within a national accounting context requires disciplines to consider measurement in new ways. For ecologists, this requires creating clear distinctions between ecosystem assets and service flows within an ecosystem and differentiating between those components 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.

1.69 It is necessary for national accountants to consider the set of goods and services produced and consumed in the context of the set of benefits provided by ecosystems and also to treat ecosystems as complex, self-regulating systems which, although they are influenced by economic activity, operate outside of the markets and property rights domains that traditionally define the measurement boundaries of the national accounts.

1.70 It is necessary for economists to examine their conceptual models concerning the links between ecosystems and the economy from an accounting perspective, and to consider the complexities of integrating new measures of assets and services with traditional economic measures.

1.71 Fundamentally, ecosystem science, economics and national accounting are disciplines that recognize the significance of systems and the multiplicity of relationships that characterize their field of interest. Ultimately, it is the aim of SEEA Experimental Ecosystem Accounting to present a systems-based approach to recording the relationships among ecosystems, the economy and society that is useful for public policymaking and environmental management.

1.5 The role of national statistical offices

1.72 There are a number of dimensions of ecosystem accounting described in SEEA Experimental Ecosystem Accounting that warrant the involvement of national statistical offices. The actual role that an individual national statistical office might play will depend on the scope of its traditional activities. For example, some national statistical offices have strong traditions in regard to work with geospatial data, and others have a history of work in development and research. Offices with these types of experience may be able to play leading roles in the development of ecosystem accounting.

1.73 Those national statistical offices without this type of experience may still play an important role. Therefore, government agencies conducting ecosystem accounting research are encouraged to utilize the kind of expertise shared by all national statistical offices, as described below.

1.74 First, as organizations that work with large and varied data sets, national statistical offices are well placed to contribute their expertise in the collection and organization of data derived from a range of different sources.

1.75 Second, a core component of the role of the national statistical offices is the establishment and maintenance of relevant definitions and classifications. At present, the area of ecosystem accounting offers many examples of cases where similar concepts are defined differently and there are multiple classifications of ecosystem services and ecosystem types. Frequently, a new study develops its own definitions and classifications. SEEA Experimental

Ecosystem Accounting represents an attempt to provide stronger guidance in this important measurement discipline and the ongoing involvement of national statistical offices in this aspect of the work would be beneficial.

1.76 Third, beyond organizing information, national statistical offices have the capability to integrate data from various sources to build up coherent representations of relevant concepts. Most commonly, national statistical offices focus on achieving coherent representations of socioeconomic information, and this capability could be expanded to encompass data concerning ecosystems. Given the multidisciplinary nature of ecosystem accounting, data integration is an important requirement.

1.77 Fourth, national statistical offices work within broad national and international data quality frameworks which enable the assessment and accreditation of various information sources and the associated methodologies in a consistent and complete manner.

1.78 Fifth, national statistical offices compile information that has a national coverage. The focus of SEEA Experimental Ecosystem Accounting is on the provision of information that permits analysis and decision-making at the national level rather than on the provision of more commonly available site or ecosystem-specific information. Creating portrayals of national economic and social structures and trends is a relatively unique function undertaken by national statistical offices, a function encompassing an implicit understanding of scaling data. Ecosystem accounting could benefit substantially from a consideration of how standard statistical techniques used for official statistics may be applied, in particular in the context of geospatial statistics.

1.79 Sixth, the voices of national statistical offices can be an authoritative one by virtue of their application of standard measurement approaches, their work within data quality frameworks and their relatively unique role within government.

1.80 A large number of national statistical offices are involved in the compilation of national accounts. The application of national accounting expertise will be highly important in the development of ecosystem accounting, particularly in the context of efforts to understand the most appropriate ways in which physical and monetary measures of ecosystem assets and services can be integrated with information in the standard national accounts. Of particular importance will be understanding those elements of ecosystem accounting that may be implicitly recorded in the standard national accounts—for example, as part of measures of agriculture production or the value of land.

1.81 All of these factors suggest that there is a distinct role for national statistical offices in the development of ecosystem accounting under a variety of possible institutional arrangements.

1.6 Structure of SEEA Experimental Ecosystem Accounting

1.82 Chapter II, entitled "Principles of ecosystem accounting", presents the accounting model for ecosystems and incorporates within the model the key concepts of ecosystems, ecosystem services and ecosystem assets. The various parts of the model are described in greater detail in later chapters. Chapter II also presents a model of statistical areas which can form a basis for ecosystem accounting, and discusses some general measurement issues that apply to all areas of ecosystem accounting.

1.83 Chapter III, entitled "Accounting for ecosystem services in physical terms", discusses the measurement of ecosystem services, highlighting key issues of scope and coverage; presents a common classification of ecosystem services; proposes basic accounting structures for recording flows of ecosystem services; and examines general issues associated with the measurement of the various types of ecosystem services. An annex contains a range of stylized examples of the measurement of ecosystem services in physical terms.

1.84 Chapter IV, entitled "Accounting for ecosystem assets in physical terms", considers measures of ecosystem extent and condition, and expected ecosystem service flows. It presents approaches to the measurement of ecosystem assets, the organization of this information into ecosystem asset accounts, and the measurement challenges involved in making overall assessments of ecosystem assets and changes in these assets, for example, due to ecosystem degradation or enhancement. Chapter IV also highlights some specific areas of accounting, namely, carbon accounting and accounting for biodiversity, and the relationship of these specific areas to ecosystem accounting more generally.

1.85 Chapter V, entitled "Approaches to valuation for ecosystem services and ecosystem assets", introduces the general concepts of value that may be utilized in ecosystem accounting and outlines the principles of valuation that are applied in the SEEA. Building on these concepts and principles, the chapter describes a range of methods commonly used in the valuation of ecosystem services and discusses their consistency with accounting concepts and principles. Chapter V also considers a range of measurement issues, including aggregation and scaling estimates for ecosystem services and ecosystem assets.

1.86 Chapter VI, entitled "Accounting for ecosystems in monetary terms", introduces the means through which estimates of ecosystem services, ecosystem assets and ecosystem degradation in monetary terms can be integrated with information in the standard national accounts. The chapter also highlights the way in which standard monetary transactions associated with ecosystems can be recognized and recorded, in particular, the treatment of payments for ecosystem services.

1.87 The annexes to chapters III, IV and VI cover approaches to measuring ecosystem services, accounting for carbon and biodiversity, and possible models for a sequence of accounts, respectively. An annotated glossary, which defines relevant terms and notes alternative terms that are commonly used, and a reference list structured by topic, have been provided.

1.88 The annex to the publication sets out a proposed research agenda for ecosystem accounting, which focuses on those areas that are considered most in need of further investigation within the context of advancing ecosystem accounting as a whole. It is anticipated that the investigation of the issues in the research agenda will be undertaken jointly across disciplines and in conjunction with ongoing research and testing programmes.

Chapter II
Principles of ecosystem accounting

2.1 An overview of ecosystems and biodiversity

Ecosystems

2.1 As noted in chapter I, the Convention on Biological Diversity defines ***an ecosystem as "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit***". Ecosystems change as a result of natural processes (e.g., succession and natural disturbances, such as a storm) or because of human actions, involving deliberate management or disturbance such as the extraction of natural resources, the introduction of invasive exotic species, or pollution.

2.2 Traditionally, ecosystems have been perceived as more or less "natural" systems, that is, systems subject to only limited human influence. However, a wider interpretation has become more common, based on the recognition that human activity is embedded within and influences ecosystems across the world.

2.3 Different degrees of human influence can be observed. For instance, in a natural forest or a polar landscape, ecosystem processes exert the dominant effect on the dynamics of the ecosystem and there are likely to be fewer impacts from human management of the ecosystem or from human disturbances. At the other end of the spectrum, in greenhouses, say, or in ponds where there is intensive aquaculture, ecosystem processes are heavily influenced by human management; and ecosystems close to and within areas of human settlement may be significantly affected by human activity and disturbances such as pollution.

2.4 Assessment of ecosystems should consider the key characteristics of the ongoing operation and location of ecosystems. Key characteristics of the operation of an ecosystem are (a) its structure (e.g., the food web within the ecosystem); (b) its composition, including living components (e.g., flora, fauna and micro-organisms) and non-living (e.g., mineral soil, air, sunshine and water); (c) its processes (e.g., photosynthesis, decomposition); and (d) its functions (e.g., recycling of nutrients and primary productivity). Key characteristics of an ecosystem's location are (a) its extent; (b) its configuration (i.e., the way in which the various components are arranged and organized within the ecosystem); (c) the landscape forms (e.g., mountain regions and coastal areas) within which the ecosystem is situated; and (d) climate and associated seasonal patterns. Ecosystems are also strongly associated with biodiversity at a number of levels. For this reason, ecosystem characteristics include within- and between-species diversity, and the diversity of ecosystem types.

2.5 Ecosystems can be identified at different spatial scales, for instance, a small pond may be considered an ecosystem, as may a tundra stretching over millions of hectares. In addition, ecosystems are interconnected, and are commonly nested and overlapping. They are subject to processes that operate over varying time scales; consequently, the scale of analysis will depend on whether there is a focus on the internal interactions within ecosystems or more broadly on relationships among ecosystem types.

2.6 It is widely recognized that ecosystems are subject to complex dynamics. ***The propensity of ecosystems to withstand pressures to change, or to return to their initial condition following natural or human disturbance, is called ecosystem resilience***. The resilience of an ecosystem is not a fixed, given property, and may change over time, for example, owing to ecosystem degradation (e.g., through timber removal from a forest) or ecosystem enhancement (e.g., through management of wetlands). Other aspects of the complex dynamics of ecosystems are reflected in the presence of thresholds, tipping points and irreversibilities. These complex dynamics and the associated non-linear relationships between the different ecosystem characteristics make the behaviour of ecosystems as a function of human and natural disturbances difficult to predict, although there have been significant improvements in the understanding of those dynamics. As far as possible, these dynamics are taken into consideration in ecosystem accounting.

Biodiversity

2.7 ***Biodiversity is defined as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems"***.[13] The scientific community has conceptualized biodiversity as a hierarchy of genes, species and ecosystems.

2.8 The processes contributing to changes in biodiversity are many and varied. Nonetheless, some generic types of processes leading to such changes at the ecosystem and species level can be identified.

2.9 At the ecosystem level, biodiversity loss is characterized by the conversion, reduction or degradation of ecosystems (or habitats). Generally, as the level of human use of ecosystems increases or intensifies above critical thresholds, biodiversity loss increases. The corollary is that increases in biodiversity, either through habitat restoration or natural succession, are shown to lead to increases in the resilience of ecosystems and increases in primary productivity.

2.10 In general, where biodiversity loss increases, many endemic species existing in a particular area will decrease in abundance, while at the same time, some species, in particular those that benefit from disturbed habitats, increase in abundance. That is, the endemic species are gradually replaced by those that are favoured by human influence (either endemic or exotic), some of which may achieve large numbers. The extinction of the endemic species is often the final step in a long process of gradual reductions in numbers. In many cases, local or national species richness (i.e., the total number of species regardless of origin) increases initially because of the introduction or favouring of exotic species by humans.[14] Because of these changes, ecosystems lose their regional endemic species and become more and more alike—a process described as "homogenization".[15]

2.11 The interconnectedness of biodiversity and ecosystems is reflected in the fact that biodiversity is a fundamental characteristic of ecosystems, and that at the same time variability among ecosystems is a fundamental driver of biodiversity. There are therefore also

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13 See Convention on Biological Diversity, article 2, entitled "Use of terms".

14 This is the so-called intermediate disturbance diversity peak (see Lockwood and McKinney (2001)).

15 Ibid.; and Millennium Ecosystem Assessment (2005), available from http://www.maweb.org/en/Reports.aspx.

important links among biodiversity, ecosystems and resilience which reflect the complex dynamics referred to above.

2.2 Key conceptual relationships in ecosystem accounting

2.12 In common with all accounting systems, ecosystem accounting is founded on relationships between stocks and flows. ***The stocks in ecosystem accounting are represented by spatial areas, each of which constitutes an ecosystem asset.***[16] Each ecosystem asset has a range of *ecosystem characteristics*—such as land cover, biodiversity, soil type, altitude and slope, climate—which describe the operation and location of the ecosystem. Some of these characteristics may be considered relatively fixed (e.g., slope and altitude), while others may be more variable (e.g., rainfall, land cover and biodiversity).

2.13 The flows in ecosystem accounting are of two types. First, there are ***flows within and between ecosystem assets which reflect ongoing ecosystem processes: these are referred to as intra- and inter-ecosystem flows***. The recognition of inter-ecosystem flows highlights the dependencies that exist between different ecosystem assets (e.g., wetlands may be dependent on flows of water from upstream).

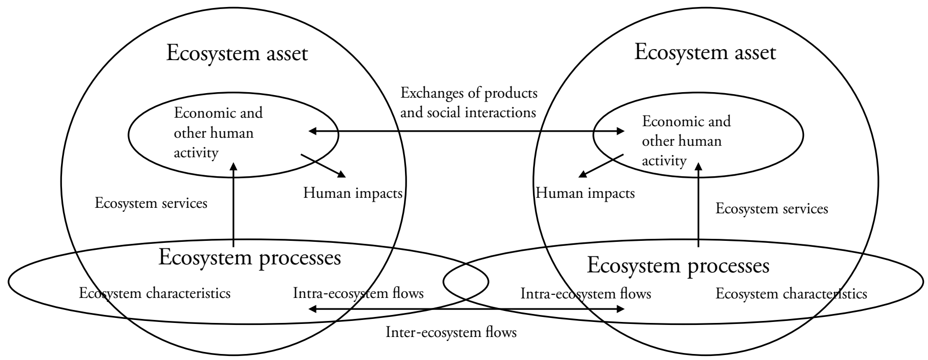
2.14 Second, ***through economic and other human activity, people take advantage of the multitude of resources and processes that are generated by ecosystem assets: collectively, these flows to people are referred to as ecosystem services***. Ecosystem services are generated through ecosystem processes that reflect the combination of ecosystem characteristics and intra- and inter-ecosystem flows. Flows of ecosystem services may relate either to flows of natural inputs from the environment to the economy (e.g., from the logging of timber resources) or to flows of residuals to the environment (e.g., emissions and waste) due to economic and other human activity. Flows of both natural inputs and residuals can impact on ecosystem assets, including on their structure, composition, processes, functions and biodiversity.

2.15 Figure 2.1 presents the basic relationships between the stocks and flows relevant in ecosystem accounting. The key feature of the figure is that each ecosystem asset represents a distinct spatial area with economic and human activity taking place within that area. Thus, the model recognizes the strong spatial relationship between ecosystems and economic and other human activity, as well as the strong connections between different ecosystem assets in terms of ecosystem processes, exchanges of economic products, ecosystem impacts of economic and other human activity, and other social interactions (e.g., the movement of people) that cross spatial boundaries.

2.16 From a measurement perspective, ecosystem accounting focuses on (a) the flows of ecosystem services to enable improved understanding of the relationship between ecosystems and economic and other human activity; and (b) the stock and changes in stock of ecosystem assets to enable an understanding of changes in ecosystems and their capacity to generate ecosystem services in the future. Changes in intra- and inter-ecosystem flows that relate to the general operation of ecosystem processes and dependencies between ecosystems are not accounted for explicitly. Rather, changes in these flows are captured through indicators of ecosystem quality which measure the effect of these processes on ecosystem assets and ecosystem services. Therefore, understanding the nature of these flows depends on an understanding of the relevant relationships.

16 The relationship between ecosystem assets and environmental assets as defined in the SEEA Central Framework is described in sect. 2.6 below.

Figure 2.1
Basic model of ecosystem stocks and flows



2.17 This basic model of ecosystem stocks and flows reflects one view of the physical relationships that exist within and between ecosystems. In practice, the relationships are far more complex than those depicted in figure 2.1. Since the model is presented in terms of stocks and flows, it can also be applied in the context of measuring the relationships in monetary terms. This dual application of the model, physical and monetary, lies at the heart of the ecosystem accounting described here and permits compilation of a comprehensive set of coherent and integrated data on the relationship between ecosystems and economic and other human activity.

2.18 Provided below is a more detailed description of this basic model. Additional discussion relating to the definition and measurement of ecosystem services and ecosystem assets is presented in subsequent chapters.

2.2.1 Ecosystem services

A model for ecosystem services[17]

2.19 Ecosystem services are central in the ecosystem accounting framework since they provide the link between ecosystem assets on the one hand, and the benefits derived and enjoyed by people on the other. Hence, they lie at the core of the relationship between ecosystems and economic and other human activity, which is the focus of environmental-economic accounting described in the SEEA.

2.20 A range of definitions and interpretations of ecosystem services have been used in various contexts ranging from site-specific case studies to large national and global assessments of ecosystems. For accounting purposes, it is most useful to consider ecosystem services in the context of a chain of flows that connect ecosystems with well-being. The overall model is shown in figure 2.2.

2.21 Starting with *individual and societal well-being*, the chained approach recognizes that well-being is influenced by the receipt of *benefits*.[18] In the context of ecosystem accounting, benefits comprise:

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17 The model of ecosystem services developed for SEEA Experimental Ecosystem Accounting is based on the findings contained in the large literature related to this topic. A list of references structured by topic is included as an annex to this publication.

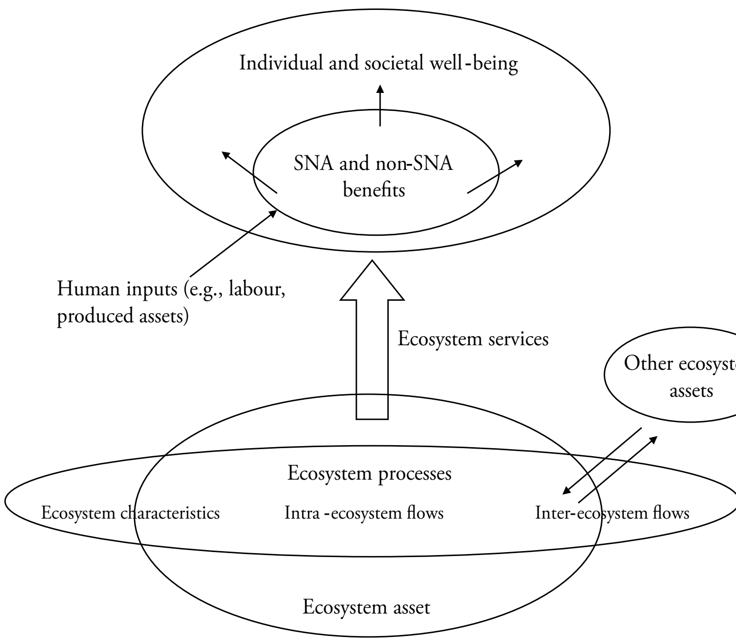
18 How benefits contribute to various components of well-being (e.g., possession of the basic materials for a good life, health, security, good societal relations, and freedom of choice and action) are not the focus of the SEEA and hence are not articulated.

(*a*) The products produced by economic units (e.g., food, water, clothing, shelter, recreation). These are referred to as *SNA benefits*, since the measurement boundary is defined by the production boundary used to measure GDP in the System of National Accounts (SNA). This includes goods produced by households for their own consumption;[19]

(*b*) The benefits that accrue to individuals that are not produced by economic units (e.g., clean air). These benefits are referred to as *non-SNA benefits*, reflecting the fact that the receipt of these benefits by individuals is not the result of an economic production process defined within the SNA. These two types of benefits may be distinguished by the fact that, in general, SNA benefits have the potential to be bought and sold on markets whereas non-SNA benefits cannot.

2.22 SEEA Experimental Ecosystem Accounting aims at providing a coherent and integrated view of all contributions made by ecosystems to human well-being. Drawing a distinction between SNA and non-SNA benefits facilitates coherence and alignment with standard national accounting measures.

Figure 2.2
Stylized model of flows related to ecosystem services



2.23 In SEEA Experimental Ecosystem Accounting, ***ecosystem services are the contributions of ecosystems to benefits used in economic and other human activity.***[20] As can be seen in figures 2.1 and 2.2, this definition excludes some flows that are considered ecosystem services in other contexts (in particular intra- and inter-ecosystem flows that relate to ongoing ecosystem processes), which are commonly referred to as supporting services. While these flows

19 The goods produced by households include outputs from subsistence agriculture, the production of energy for own consumption, and the collection of water. It is noted that SNA benefits exclude services provided by households for their own consumption, such as meal preparation and childcare (the exception is housing services produced through ownership of dwellings, which are included).

20 In this context, "use" includes both the transformation of materials (e.g., use of timber to build houses or for energy) and the passive receipt of non-material ecosystem services (e.g., the amenity of viewing landscapes).

are not considered ecosystem services, they are not ignored in ecosystem accounting and are incorporated in the measurement of ecosystem assets.

2.24 The model of ecosystem services takes no explicit account of so-called ecosystem disservices such as pest infestation and disease. To some extent, these flows will be reflected in reduced flows of some ecosystem services (e.g., lower flows of provisioning services). Chapter III discusses this issue further.

2.25 Defining ecosystem services as "contributions" highlights the fact that ecosystem services are only one part of a broader set of inputs which are combined to provide benefits. For example, the benefit of clean drinking water is, most commonly, the end result of the abstraction of water from an ecosystem through the use of human inputs of labour and produced assets (e.g., pipes, wells, filtration equipment). These combinations of inputs may be considered examples of joint production and are a feature of the production of SNA benefits.

2.26 On the other hand, there are usually few human inputs into the generation of non-SNA benefits; hence, the ecosystem service and the associated benefit may, in effect, be equivalent (e.g., the benefit of clean air from the ecosystem service of air filtration provided by trees and other plants). By convention, the measurement scope of non-SNA benefits for ecosystem accounting purposes is limited to the flow of ecosystem services with an identifiable link to human well-being.

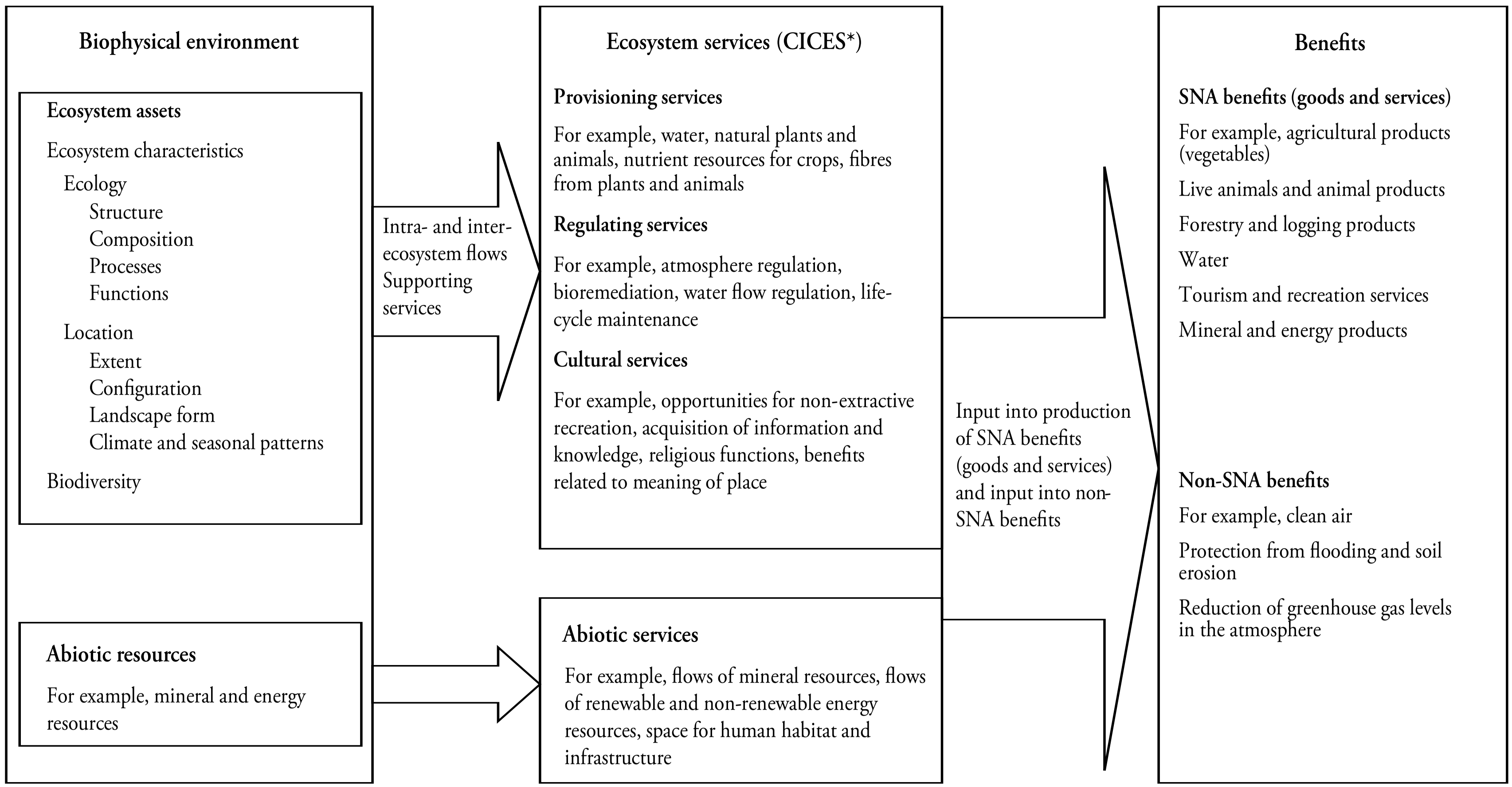
2.27 Ecosystem services result not only from the harvesting or extraction of materials from an ecosystem, but also from its general functioning (e.g., provision of clean air through air filtration services by trees) and from other characteristics of an ecosystem (e.g., enjoyment of spectacular views of the physical structure and composition of mountain landscapes). Thus, the term "services" as used here encompasses all of the ways in which humans may benefit from ecosystems.

2.28 Ecosystem services do not encompass the complete set of flows from the environment. Important examples of other environmental flows include the extraction of mineral and energy resources, use of energy from the sun for the growing of crops and use of the sun as a renewable source of energy, and the movement of wind and the tides, which can be captured to provide energy. More broadly, the environment provides the space in which economic and other human activity takes place, and the provision of space may be conceptualized as an environmental flow. Collectively, these other environmental flows are referred to as *abiotic services*. The relevant boundary issues are discussed further in chapter III.

2.29 Regarding the series of flows related to ecosystem services, it is important to recognize that ecosystems do not function only to generate ecosystem services. While many intra- and inter-ecosystem flows do not benefit humans directly, they do support the functioning and resilience of ecosystems, which in turn makes it possible to generate ecosystem services now and will make it possible to do so in the future. Therefore, the multitude of flows and characteristics that are the basis for functioning ecosystems are all relevant and their impact can be captured by accounting for ecosystem assets.

2.30 Figure 2.3 offers one model of the relationships between ecosystem services and the other relevant ecosystems-related measures. It places ecosystem services in the context of the biophysical environment, ecosystem assets, ecosystem processes, ecosystem characteristics, abiotic services and benefits. The figure highlights the variety of relationships and connections between the physical earth and the benefits used in economic and other human activity. Chapter III discusses in greater detail the relevant measurement boundaries that need to be defined to ensure appropriate accounting for ecosystem services.

Figure 2.3
Broad model of flows in ecosystem accounting



* Common International Classification of Ecosystem Goods and Services

2.2.2 Central concepts in measuring ecosystem assets

2.31 ***Ecosystem assets are spatial areas comprising a combination of biotic and abiotic components and other characteristics that function together.*** Ecosystem assets are measured from two perspectives—that of *ecosystem condition* and *ecosystem extent*; and that of *ecosystem services*. A particular combination or "basket" of ecosystem services will be generated at a particular point in time from a specific ecosystem asset. The aggregation of all future ecosystem services for a given basket provides an estimated stock of *expected ecosystem service flows*, at a point in time.

2.32 In general terms, the capacity of an ecosystem asset reflects the relationship between the characteristics of the asset and its expected uses (determined by the expected baskets of ecosystem services to be generated). The capacity of the ecosystem asset to continue to generate ecosystem services into the future will change as a function of changes in the condition and extent of the ecosystem asset and in response to changes in the expected flows of ecosystem services. Thus, for an expected basket of ecosystem services at a given point in time, an ecosystem asset may be considered to be generating services below, at or above its capacity to generate those services. In the context of a single resource, timber, for example, the notion of capacity may be aligned with the concept of a sustainable yield. However, where a mix of ecosystem services is generated, determination of the sustainable yield across the different services, which may be produced in tandem or in competition, will be quite complex. Ecosystem services are recorded only when there are associated benefits to economic or other human activity. Consequently, for accounting purposes, there can be no case arising of "unused" ecosystem services if an ecosystem asset is considered to be generating services below its capacity.

2.33 The capacity of an ecosystem asset should be distinguished from its potential to be used for different purposes and hence generate alternative baskets of ecosystem services. For example, a forest ecosystem may be used primarily for logging or for recreation. The differing potential amounts of ecosystem services that could be generated from different ecosystem-use scenarios can be assessed using the same accounting framework described here and such comparisons may be important analytical outputs. However, the assessment of alternative scenarios should be distinguished from accounting for an expected basket of ecosystem services, which is the focus from an accounting perspective.

2.34 Overall, the relationship between the condition and extent of ecosystem assets and the expected ecosystem service flows is not a simple one, and it is likely to be non-linear and variable over time. As a result of the issue's complexity, knowledge of the relationships between ecosystem condition and extent, and future flows of ecosystem services is incomplete, although it is an area of active ecological research. For ecosystem accounting, both approaches to the measurement of ecosystem assets are needed, since it cannot be assumed that measurement from only one perspective will be able to provide a comprehensive assessment of ecosystem assets. If the focus of measurement is on well-defined spatial areas (see sect. 2.3), then these two perspectives can be so integrated as to provide a more complete picture of ecosystem assets and the changes therein.

Ecosystem condition and ecosystem extent

2.35 ***Ecosystem condition reflects the overall quality of an ecosystem asset in terms of its characteristics.*** The assessment of ecosystem condition involves two distinct stages of measurement with reference to both the quantity and the quality aspects of the characteristics of the ecosystem asset. In the first stage, it is necessary to select appropriate characteristics and associated indicators of changes in those characteristics. The selection of characteristics and associated indicators should be carried out on a scientific basis so that there is an assessment of the ongoing functioning, resilience and integrity of the ecosystem asset. Thus, movements of the indicators should be responsive to changes in the functioning and integrity of the ecosystem as a whole.

2.36 Measures of ecosystem condition may be compiled in relation to key ecosystem characteristics (e.g., water, soil, carbon, vegetation, biodiversity) and the choice of characteristics will generally vary depending on the type of ecosystem asset. Further, the selection of characteristics should take into account current and expected future uses of the ecosystem (e.g., whether for agriculture, forestry, carbon sequestration, recreation), since these uses are likely to impact most directly on certain characteristics and hence on the overall condition and capacity of the ecosystem asset to generate alternative baskets of ecosystem services. Usually, there will not be a single indicator for assessing the quality of a single characteristic. Both the selection and measurement of characteristics and associated indicators are likely to present measurement challenges.

2.37 In the second stage, the indicators are related to a common reference condition or benchmark. Several alternative conceptual bases for determining the reference condition are described in chapter IV. The use of a common reference condition relative to all indicators for an ecosystem asset may allow an overall assessment of the condition of the asset.

2.38 ***Ecosystem extent refers to the size of an ecosystem asset.*** For ecosystem assets, the concept of extent is generally measured in terms of surface area, for example, hectares of a land-cover type.[21] Where there is a mix of land covers within an ecosystem asset (e.g., a river basin or a mixed agricultural landscape), ecosystem extent may be reflected in the proportion of different types of land cover. Changes in the proportions of different land covers within a defined spatial area may be important indicators of changes in ecosystem assets.

2.39 The measurement of biodiversity is intertwined with measures of ecosystem condition and extent in a number of ways. First, measures at the species level of biodiversity within an individual ecosystem asset are likely to provide a useful indicator of changes in the condition of that asset. Second, measures of changes in the composition of ecosystem assets in terms of changing extent and distribution of different land-cover types (and associated measures of fragmentation of the landscape) are likely to reflect changes in biodiversity at the ecosystem level. Third, measures of changes in biodiversity at the ecosystem level will themselves provide an indication of changes in habitat and thus changes in biodiversity at the species level—for example, effects on the abundance and richness of species. The potential to undertake accounting for biodiversity at the species level is discussed in detail in sect. 4.5.

Expected ecosystem service flow

2.40 ***Expected ecosystem service flow is a measure of all future ecosystem service flows from an ecosystem asset for a given basket of ecosystem services.***[22] The expected flows must be based on an expected basket of provisioning, regulating and cultural services from an ecosystem

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21 Land cover is most easily associated with terrestrial ecosystems (e.g., forest, grassland, tundra). Aquatic ecosystems may be classified by type of water cover (e.g., inland water bodies, coastal water bodies, open wetlands) but also through aquatic ecosystem mapping systems which distinguish between marine, estuarine, riverine, palustrine and lacustrine environments (see, e.g., Cowardin (1979)). These mapping systems may consider different aquatic habitats (e.g., reefs and seagrass) and factors such as depth and light availability.

22 This is akin to the concept of the productive capital stock as developed in the context of measuring the capital services from produced assets. The productive capital stock is the measure of an asset at a point in time in terms of the aggregate number of efficiency units of capital services that it is expected to deliver over its lifetime.

asset. Generally, for accounting purposes, the expected basket of ecosystem services would be based on the current patterns of use.

2.41 Because the generation of some ecosystem services involves the extraction and harvest of resources, and since ecosystems have the potential to regenerate, it is necessary to form some conception of the levels of extraction and regeneration that will be involved, and on the overall sustainability of human activity in the ecosystem. This will require information concerning likely changes in ecosystem condition, underpinned by the basic assumption that the future flows of the relevant ecosystem services will be constant.

2.42 As noted, there will be complex and non-linear relationships among the condition of an ecosystem asset, its pattern of use, and the expected basket of ecosystem services. Consequently, estimation of the future flows of ecosystem services will require assumptions about these relationships.

Changes in ecosystem assets

2.43 Measures of ecosystem condition and extent, and measures of expected ecosystem service flows are all stock measures at a point in time. In accounting, they are most commonly measured at the beginning and end of the accounting period. Often, however, there is also interest in measuring changes in ecosystem assets. Following the logic of the asset accounts described in the SEEA Central Framework, accounting entries may be defined that reflect the various additions to and reductions in an ecosystem asset over the course of an accounting period.

2.44 In some cases, the measurement of changes in ecosystem assets is a relatively straightforward exercise. Of interest may be the changes in ecosystem extent, commonly reflected in changes in land cover. Changes in ecosystem condition and expected ecosystem services flows (calculated as the differences in stocks between the beginning and the end of the period) may also be of interest, particularly if assessed over a number of accounting periods.

2.45 However, for accounting purposes, there is most interest in recording the changes over an accounting period and attributing them to various causes. In the context of ecosystem accounting, there is interest in changes due to economic and other human activity as distinct from natural causes, and changes due to extraction as distinct from regeneration and growth. Two particular accounting entries in this context are ecosystem degradation and ecosystem enhancement. A description of these and other changes in ecosystem assets is provided in chapter IV.

2.3 Units for ecosystem accounting

2.3.1 Introduction

2.46 The coordinated measurement of ecosystems followed by comparison and analysis of information across time and between ecosystems requires a clear focus for measurement. For accounting purposes, well-defined boundaries are needed which can be applied at specific scales of analysis and which are suitable for the organization of information and the presentation of accounts.

2.47 Boundaries for specific ecosystems are generally drawn on the basis of relative homogeneity of ecosystem characteristics, and with a view to ensuring stronger internal functional relations than external ones. However, as these boundaries are often diffuse and established gradually, a definitive boundary between two ecosystems may be difficult to establish. Furthermore, one ecosystem may be very small and another very large and they will therefore operate at different spatial scales.

2.48 Statistical units are the entities about which information is sought and about which statistics are ultimately compiled. It is the statistical unit that provides the basis for the compilation of statistical aggregates and to which tabulated data refer.[23] In economic statistics, the statistical units are the various establishments, enterprises, government and household entities about which economic data are collected. Generically, these are referred to as economic units.[24] Economic units may be grouped, for analytical purposes, into industries (units undertaking similar economic activities) or institutional sectors (units with similar types of legal bases and behaviours).

2.49 ***The statistical units of ecosystem accounting are spatial areas about which information is collected and statistics are compiled***. Such information is collected at a variety of scales using a number of different methods, including remote sensing, on-ground assessment, surveys of landowners and use of administrative data.

2.50 Three different, but related, types of units are defined in SEEA Experimental Ecosystem Accounting to accommodate the different scales and methods used to collect, integrate and analyse data. They are: basic spatial units (BSUs), land-cover/ecosystem functional units (LCEUs) and ecosystem accounting units (EAUs). Each type of unit is described below.

2.51 The relationships among the three types of units can be viewed in either a bottom-up (i.e., starting with the BSU) or a top-down (i.e., starting with the EAU) manner. That is, the BSUs may be aggregated to form LCEUs or EAUs, or the LCEUs or EAUs may be disaggregated to form BSUs. Direct measurement may be conducted at each level, depending on the concept being measured.

2.52 The units model described in the present section may appear prescriptive but in fact it is intended only to indicate that ecosystem accounting requires the delineation of spatial areas and that an approach that delineates spatial areas of different sizes is an appropriate one. The logic presented in this section is capable of being implemented in a flexible manner and, through testing, additional guidance will be provided.

2.3.2 Basic spatial units

2.53 A basic spatial unit is a small spatial area. Ideally, the BSU should be formed by delineating small areas known as tessellations (e.g., of 1 square kilometre (km^2)), typically by overlaying a grid on a map of the relevant territory, but BSUs may also be land parcels delineated by a cadastre[25] or by using remote-sensing pixels. Grid squares, each ideally a BSU, are delineated to be as small as possible given available information, landscape diversity and analytical requirements. The model can also accommodate different scale grids through spatial nesting (e.g., nesting of a grid of 100 square metres (m^2) within a 1 km^2 grid). It is particularly advantageous for each BSU to refer to the same spatial area over time.

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23 Statistical units should be distinguished from units of measurement, such as money, tonnes and hectares, which provide a common basis for the recording of specific variables.

24 See the glossary for more detailed definitions of relevant terms. An overview of economic units is provided in the SEEA Central Framework (chap. II) and complete descriptions of economic units from the perspective of national accounting are provided in chapter IV of the *System of National Accounts 2008* (European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, United Nations and World Bank, 2009).

25 A cadastre is a register of properties in a region or country with information on the ownership, tenure, location, size and value of each property.

2.54 After delineation, each BSU can be attributed with a basic set of information. The most common starting point for this attribution process will be information on the location of the unit and land cover. This basic information is then extended with information relevant to the purpose of the account being compiled, including ecosystem characteristics such as soil type, groundwater resources, elevation and topography, climate and rainfall, species present and their abundance, the degree of connection to related areas, current or past land uses, landownership, location relative to human settlement, and the degree of accessibility to the area by people.

2.55 This information may be extended to include information on the generation of different ecosystem services from the BSU so that the BSU can represent the level at which all relevant information for ecosystem accounting is assimilated and organized. Since ecosystem services are often generated over areas larger than a single BSU, a method is required to attribute information to the BSU level. This issue is discussed in chapter III.

2.56 If possible, information on any associated economic units, for example, landowners, should be attributed to each BSU. Underlying the utilization of this range of information is recognition of the fact that, while each BSU is a mutually exclusive area, it can be linked to a number of other spatial areas (e.g., an EAU) and that ecosystem assets and ecosystem services may operate at varying spatial scales and be linked to more than one economic unit. The link to economic units is discussed further in section 2.3.6.

2.3.3 Land-cover/ecosystem functional units

2.57 The second type of unit is the land-cover/ecosystem functional unit (LCEU). For most terrestrial areas, the area, and by extension, the LCEU should satisfy a predetermined set of criteria relating to the characteristics of an ecosystem. Examples of these characteristics include land-cover type, water resources, climate, altitude and soil type. A particular criterion is that it should be possible consistently to differentiate an LCEU from neighbouring LCEUs based on differences in its ecosystem characteristics.

2.58 The resulting LCEU would commonly be considered an ecosystem although, strictly speaking, ecosystems cannot be defined in purely spatial terms. LCEUs may be disaggregated into BSUs (e.g., by overlaying a grid) or BSUs may be aggregated to form LCEUs (i.e., the LCEU encompasses a set of contiguous BSUs, each having the same core characteristics). Aggregation could take place following standard approaches to statistical classification, with BSUs being classified to a particular LCEU on the basis of a predominance of particular characteristics within the BSU. For example, if the predominant characteristic of a BSU was forest tree cover, that BSU would be combined with similar adjacent BSUs to form an LCEU with the predominant characteristic of forest tree cover. This is akin to classifying an establishment to a particular industry based on the predominance of a particular economic activity in that establishment.

2.59 A provisional set of (15) classes for land-cover/ecosystem functional units is presented in table 2.1. The classes are based on the Food and Agriculture Organization of the United Nations (FAO) Land Cover Classification System, version 3 (LCCS 3) (Food and Agriculture Organization of the United Nations, 2009). This approach uses as its starting point the classes of the Land Cover Classification presented in chapter V of the SEEA Central Framework (which is also based on LCCS 3) and combines these into classes that are optimized for the analysis of changes in land cover and land use. The LCEU classes can be augmented by other characteristics relating, for example, to broad climatic zone (e.g., tropical, subtropical and temperate), elevation (e.g., presence of lowlands and highlands) and topography (e.g., presence of plains and mountains).

2.60 LCEUs will vary in size depending on the situation in a given country. Also, not all countries will have all types of LCEUs (as listed in table 2.1). Various instruments, studies and reports (e.g., the Convention on Biological Diversity, the Millennium Ecosystem Assessment and the UK National Ecosystem Assessment) have used different classifications but all use terms that are considered commonly understood (e.g., "forest", "wetland", "grassland" and "coastal area").

2.61 At any point in time, all LCEUs should be mutually exclusive, i.e., each BSU should be within only one LCEU. However, over time, as changes in land cover and land use occur, some BSUs will need to be reclassified to different LCEUs—for example, from "Agriculture associations and mosaics" to "Urban and associated developed areas".

2.62 The LCEU delineates an area for which accounting may be undertaken and hence LCEUs may be considered ecosystem assets. For smaller-scale analysis, it may be relevant to undertake accounting for a single LCEU. At national levels, there is likely to be interest in aggregation of information about specific types of LCEUs wherever they are located; information concerning, for example, open woodlands or wetlands in a country or region, and also comparison of different types of LCEUs across a country.

Table 2.1
Provisional land cover/ecosystem functional unit classes

Description of classes
Urban and associated developed areas
Medium to large fields of rain-fed herbaceous cropland
Medium to large fields of irrigated herbaceous cropland
Permanent crops, agriculture plantations
Agriculture associations and mosaics
Pasture and natural grassland
Forest tree cover
Shrubland, bushland, heathland
Sparsely vegetated areas
Natural vegetation associations and mosaics
Barren land
Permanent snow and glaciers
Open wetlands
Inland water bodies
Coastal water bodies
Sea

2.63 It is likely that LCEUs represent the closest approximation to ecosystems in spatial terms given how large ecosystems are commonly envisaged. However, in order to more fully adapt LCEU delineation to ecosystem types, it may be necessary to allow for variations in climatic and geophysical conditions and land use. For example, in some countries, the class "Forest tree cover" may encompass substantial differences in canopy cover of a given area. For some purposes, it may be relevant to cross-classify LCEUs by the extent to which the area is considered influenced by human activity. Thus, given types of LCEUs (e.g., forest tree cover) could be regarded as representing natural, semi-natural, agricultural or other kinds of ecosystems.

2.64 As noted above, table 2.1 presents a provisional list of classes for land-cover/ecosystem functional units (LCEUs). The development of this classification has been included in the research and testing agenda.

2.3.4 Ecosystem accounting units

2.65 The nature of the delineation of an EAU is based on the purpose of analysis and should therefore take into consideration administrative boundaries, environmental management areas, large-scale natural features (e.g., river basins) and other entities relevant to defining areas for reporting purposes (e.g., national parks and other protected areas). Overall, the EAU should be a relatively large area in regard to which there is interest in understanding and managing change over time. Consequently, EAUs should be spatial areas that are fixed or largely stable over time and, for accounting purposes, may be considered ecosystem assets.

2.66 Depending on the size of the country, there may be a hierarchy of EAUs built up from smaller reporting units that reaches the national level. For example, starting from a local administrative unit, a hierarchy of EAUs may be built up to the provincial and then the national level. In all cases, a country's total area will represent the single highest level in a hierarchic EAU structure.

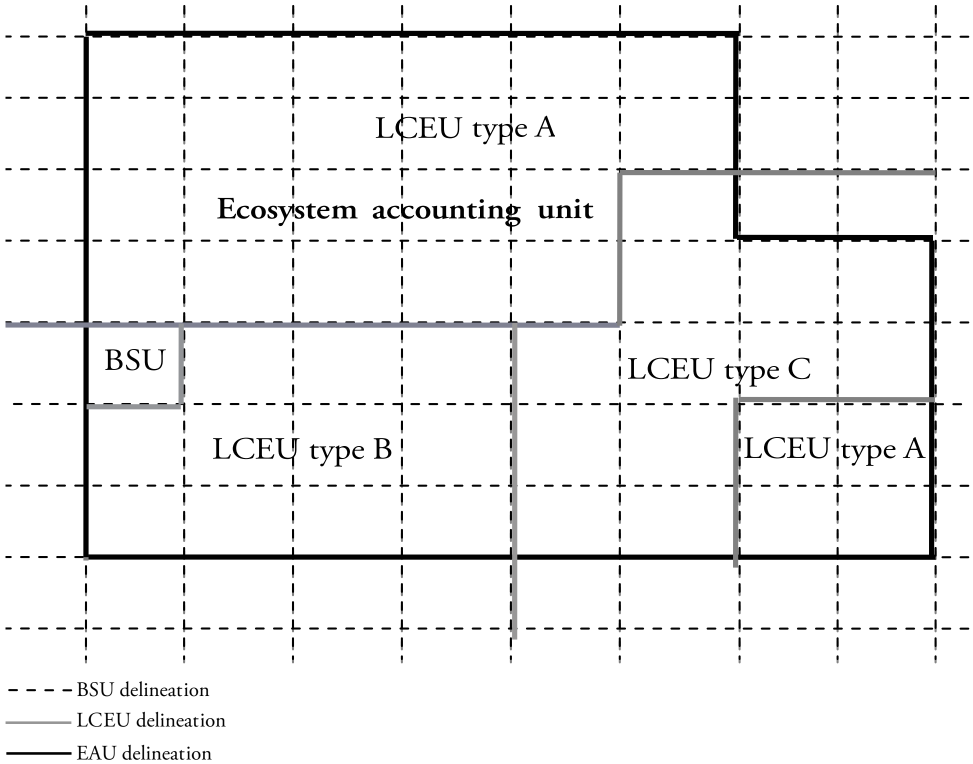
2.67 A specific concept has been developed that may be useful in the delineation of EAUs, namely, that of socio-ecological systems. Areas defined as socio-ecological systems integrate ecosystem functions and dynamics as well as human activities and the range of interactions of these components.

2.68 For the purposes of national-scale ecosystem accounting, it is recognized that EAUs are likely to contain a range of ecosystem types (reflected in different types of LCEU) and generate a range of ecosystem services.

2.69 For a single country, it may be relevant to recognize different hierarchies of EAUs. For example, a set of EAUs may be delineated based on administrative regions, a second set may be based on catchment management areas, and a third set may be based on soil types. All EAUs within each set may be aggregated to form national totals but there should not be an aggregation of EAUs across different sets (e.g., aggregation of some administrative regions with some catchment areas), since this would imply the aggregation of "non-matching units" and the potential to double-count individual areas.

2.70 Figure 2.4 provides a stylized depiction of the relationships between BSUs, LCEUs and EAUs where, in this case, the BSUs are defined by grid squares. Attribution of BSUs to LCEUs and to EAUs should be based on predominance, as described above. Note that it is possible for a number of LCEU types to be present within a single EAU and for a single LCEU type to appear in various locations within an EAU.

Figure 2.4
Stylized depiction of relationships between BSUs, LCEUs and EAUs



2.3.5 Spatial units in relation to ecosystem services

2.71 Since any given spatial area may generate a number of types of ecosystem services, it is likely that a single BSU will be involved in the generation of a range of ecosystem services. In this sense, there is no direct correlation between a BSU and, in the area of economic statistics, an establishment that undertakes a single kind of activity.

2.72 In addition, it is likely that a range of ecosystem services are generated over a larger spatial area than a single BSU, or are at least measured over areas larger than a single BSU. This being the case, it may be useful to map areas that are relevant to the generation of particular ecosystem services. Often, these maps will contain a contiguous set of BSUs (e.g., in the case of provisioning services from a forest); but this need not be the case. It is also possible that some ecosystem services are generated within a single BSU (e.g., cultural services from a local fishing site).

2.73 Although the generation of ecosystem services may occur over a variety of spatial areas depending on the service, for a broad range of services, a useful first step in measurement may be to consider the ecosystem services generated within an LCEU. Since provisioning services, and some regulating and cultural services, are closely associated with land cover, an LCEU provides a useful spatial boundary. Maps of ecosystem services generation may be useful tools in delineating LCEUs by facilitating an understanding of how related ecosystem services are concentrated, with each ecosystem service likely to have its own specific area over which it is generated. By linking maps of service generation to LCEUs delineated by land cover, the relationship between land cover and service generation can be tested.

2.3.6 Relationship to economic units

2.74 The cross-classification of ecosystem information and economic units is central to an assessment of the relationship between ecosystem services, ecosystem assets and economic activity. The application of ecosystem-related information to questions of land management and ecosystem degradation requires that such connections be made.

2.75 Ideally, the link to economic units would be undertaken in the process of delineating spatial units, for example, using information on land use or landownership (derived from cadastres) within the broader process of delineating BSUs or LCEUs. If this detailed linking is not possible, then broader assumptions may be applied, for example, through attributing information on land use or landownership to BSUs or LCEUs.

2.76 For certain ecosystem services, it may be relevant to use economic units as a basis for collecting relevant data, and most relevant in respect of provisioning services, for example, related to timber, or cultural services, such as recreation.

2.77 It should be noted that the beneficiaries of the ecosystem services may be land users or landowners or people living nearby (as is the case for air filtration) or populations at large (as is the case for carbon sequestration). Further, in specific situations, the beneficiaries may be spatially delineated, as in the case of people living downstream in the flood zone of an upper catchment that is managed with the aim of protecting its hydrologic services.

2.3.7 Issues in the delineation of spatial units

Geographic information systems

2.78 The delineation of units should be undertaken in concert with the development of spatial databases in geographic information systems (GIS). These databases could contain information on, for example, soil type and status, water tables, rainfall amount and pattern, temperatures, vegetation, biodiversity, slopes, altitude, as well as, potentially, information on land management and use, population, and social and economic variables. This information might also be used to assess flows of ecosystem services from given spatial areas to relevant beneficiaries.

Units for the atmosphere, marine areas and linear features, including rivers

2.79 In presenting accounts for ecosystems at a national level, the geographical scope of the accounts should be clearly stated. Often, the scope may be limited to terrestrial areas and inland water bodies; but there may be good reasons to extend the coverage so as to incorporate marine areas under the control of a national administration. In the context of the SEEA, this is considered to extend to the country's exclusive economic zone (EEZ).

2.80 The boundaries of a country's atmosphere should align with the terrestrial and marine boundaries used in the ecosystem accounts. Thus, in principle, it would consist of all air volumes directly above the areas whose scope is stated in the accounts, potentially extending out to the limit of the EEZ. Within this boundary, it may be useful to delineate the atmosphere into smaller units, for example, "airsheds" associated with individual cities.

2.81 Particular care should be taken in (a) determining the treatment of coastal ecosystems that straddle terrestrial and marine areas; (b) delineating areas related to rivers, such as flood plains; (c) considering other linear features; and (d) defining aquatic ecosystems such as wetlands. It is also important that the delineation of marine areas take into account not only the area but also the operation of ecosystems at varying depths and on the sea floor.

2.82 Although much relevant research on these matters has been conducted, the delineation of relevant units and their integration with the terrestrial units described in the present section have not been completed within the context of ecosystem accounting. This task has therefore been placed in the research agenda.

2.4 Ecosystem accounting tables

2.83 To provide a basis for understanding the nature of ecosystem accounting, this section presents some possible ecosystem accounting tables. The tables focus on the recording of information in physical terms related to flows of ecosystem services and to stocks of ecosystem assets. All of the tables are designed to give a broad idea of the potential of ecosystem accounting to organize information across a range of areas and from multiple perspectives. They are experimental in design and should serve only as a starting point for compilation and testing. The compilation of and possible extensions to these tables are discussed in chapters III and IV.

2.4.1 Tables for ecosystem services

2.84 Tables for ecosystem services aim primarily to organize information on the flows of ecosystem services by type of LCEU. It may also be relevant to present information in terms of the economic units involved in generating and using the various services.

2.85 The objective from an analytical perspective is to use information on the combinations of ecosystem services within an ecosystem asset (i.e., the observable basket of ecosystem services) to determine what trade-offs may arise from alternative uses. Further, this information can be used to construct scenarios depicting the flows of ecosystem services in response to anticipated activities in an ecosystem asset, activity in neighbouring ecosystems, natural changes in ecosystem processes or climate change.

2.86 Usually, ecosystem services are interconnected. They may be generated in tandem or enhanced by the generation of other ecosystem services or may compete with other services. For example, the provisioning service of timber and the regulating service of air filtration are competing services within forest ecosystems (at the time of and after timber harvest), while air filtration and carbon sequestration services are generated in tandem. Analysis should be undertaken in the light of the various social and ecosystem factors that may affect the reported area.

2.87 Table 2.2 provides a basis for reporting information on physical flows of ecosystem services for an EAU or a country as a whole. The number of different ecosystem services reported will vary depending on the type of ecosystem and its pattern of use. The ecosystem services shown in table 2.2 will not be measured using the same physical units and hence totals across different ecosystem services are not shown.

2.88 Aggregation across different ecosystem services may be undertaken in different ways, all requiring some assumptions regarding the relative importance of each service. Chapter III describes possible extensions to the basic table shown below and approaches to aggregation.

Table 2.2
Physical flows of ecosystem services for an EAU

Type of ecosystem services (by CICES)	Type of LCEU: Forest tree cover	Agricultural land[a]	Urban and associated developed areas	Open wetlands	…
Provisioning services	For example, tonnes of timber	For example, tonnes of wheat			
Regulating services	For example, tonnes of CO_2 stored/released	For example, tonnes of CO_2 stored/released	For example, tonnes of CO_2 stored/released	For example, tonnes of phosphorus absorbed	
Cultural services	For example, number of visitors and hikers		For example, hectares of parkland	For example, hectares of habitat for ducks	

a Medium to large fields of rain-fed herbaceous cropland.

2.4.2 Tables for ecosystem assets

2.89 Given the range of concepts involved in the measurement of ecosystem assets, a number of tables may need to be compiled. Tables concerning ecosystem extent are largely derived from the asset accounts for land described in the SEEA Central Framework. Most important are measures of the area of different LCEUs, which may be developed along the lines explained for land-cover accounts (see SEEA Central Framework, sect. 5.6).

2.90 Some information concerning indicators of ecosystem condition may be compiled in basic resource accounts, for example, accounts for cubic metres of water resources, tonnes of timber resources and tonnes of carbon. These accounts can provide information related to quantitative changes in ecosystem condition (e.g., reductions in water flow and increases in tree cover) and their compilation is generally more straightforward than accounts providing information on more qualitative aspects of ecosystem condition.

2.91 The relevant accounting for water, timber and other resources, which includes the measurement of opening and closing stocks and changes in stocks, is described in detail in the SEEA Central Framework. Accounting for carbon is discussed in section 4.4 of this publication. The extension for ecosystem accounting purposes is so that the information on the stocks of resources be attributed to ecosystem assets (i.e., spatial areas), and hence flows between ecosystem assets (inter-ecosystem flows) should also be recorded.

2.92 Relevant information from these sources together with additional indicators for specific ecosystem characteristics may be presented in a table like table 2.3, which refers to the stock at the end of the accounting period. Appropriate extensions to this table would enable consideration of the opening stock and changes in stock.

2.93 Table 2.3 relates to a specific EAU (or a country as whole) and is structured by type of LCEU, it being understood that in a given EAU there is likely to be a mix of different LCEU types. It would be possible to also include information on relevant benchmarks and thresholds for different indicators alongside the observed information so as to provide a basis for assessing changes in overall ecosystem condition. Information on each indicator will be collected using different measurement units but may be adjusted for the purposes of comparison through the use of reference conditions and other approaches.

Table 2.3
Measures of ecosystem condition and extent for an EAU at end of accounting period

Type of LCEU	Ecosystem extent	Characteristics of ecosystem condition				
		Vegetation	Biodiversity	Soil	Water	Carbon
		Examples of indicators				
	Area	Leaf area index, biomass, mean annual increment	Species richness, relative abundance	Soil organic matter content, soil carbon, groundwater table	River flow, water quality, fish species	Net carbon balance, primary productivity
Forest tree cover						
Agricultural land[a]						
Urban and associated developed areas						
Open wetlands						

a Medium to large fields of rain-fed herbaceous cropland.

2.94 Measures of ecosystem condition should cover the main characteristics of each ecosystem type that affect the ongoing functioning, resilience and integrity of the ecosystem. The listed aspects of vegetation, biodiversity, soil, water and carbon are indicative only. The selection of characteristics and the development of indicators for ecosystem condition should be completed in close consultation with ecologists and other scientists and informed by ongoing experimentation and testing.

2.95 The goal of this table is to present indicators of ecosystem extent and condition for each LCEU type. Possible approaches to aggregation and considerations related to assessing change in condition are discussed in chapter IV.

2.96 Table 2.4 presents a basic structure for presenting information on expected ecosystem service flows. As with the measures of ecosystem services shown in table 2.2, the measurement units for the entries in this table will be different, depending on the particular service. In situations where the current use of a particular ecosystem service exceeds the ecosystem's capacity to generate that service sustainably, it will be possible to determine a total of expected flows over an ecosystem life. For example, for a forest that is completely cleared over a period of years without regeneration, the expected ecosystem provisioning service flow of timber will be limited to the remaining timber available divided by the number of years taken to clear the forest.

2.97 However, in situations where sustainable use is being made of the ecosystem, the estimated expected flows into the future are infinite. An aggregate may be derived by setting a standard asset life, such as 25 years, over which analytical assumptions are not expected to change. An alternative is to measure the expected ecosystem service flows in terms of expected flows per year, with the understanding that this may be greater or less than an independently derived estimate of a sustainable flow. Measures of expected ecosystem service flows should be clearly linked to the measures of flows of ecosystem services shown in table 2.2.

2.98 Measures of expected ecosystem service flows will be challenging to estimate in light of the complex and non-linear relationships between ecosystem services flows and ecosystem condition. Various assumptions and close collaboration between compilers and scientists will be needed in order to model the expected flows given assumed patterns of use and expected ecosystem responses (dose-response functions).

Table 2.4
Expected ecosystem service flows at end of accounting period

	Expected ecosystem service flows per year				
Type of ecosystem services	Forest tree cover	Agricultural land[a]	Urban and associated developed areas	Open wetlands	…
Provisioning services					
Regulating services					
Cultural services					

a Medium to large fields of rain-fed herbaceous cropland.

2.99 A potential extension to table 2.4 would relate the expected ecosystem service flows to relevant economic units. In this way, assessments of trade-offs between alternative baskets of ecosystem services could be additionally informed by data related to social and economic activity.

2.100 Accounting for changes in ecosystem assets is a complex task, especially with regard to defining and accounting for ecosystem degradation. The relevant issues are discussed in chapter IV.

2.5 General measurement issues in ecosystem accounting

2.101 The present section introduces a number of general measurement issues that may arise in the course of compiling ecosystem accounts. These issues involve: (a) the integration of information across different spatial scales, (b) the transfer of data, (c) gross and net recording and (d) the length of the accounting period. The fact that these are primarily practical issues does not diminish the importance of giving them due consideration when practising ecosystem accounting based on the general model presented in this chapter.

2.5.1 The integration of information across different spatial scales

2.102 A primary objective of ecosystem accounting is the organization of information sets for the analysis of ecosystems at a level suitable for the development, monitoring and evaluation of public and private policy. Consequently, consideration must be given to collecting and collating information pertaining to many ecosystems across a region or country. To meet other objectives for the organization of information on ecosystems, such as the assessment of specific ecosystems or local development projects, there is less of a requirement to consider alignment of scales of measurement, since the ecosystem can be delineated in a manner relevant to the given analysis. However, for macrolevel accounting and long-term monitoring, such individualized specification of the scale of analysis is not appropriate and more structured approaches are required.

2.103 There are significant measurement challenges that need to be addressed in using spatial data, particularly concerning the aggregation and disaggregation of those data. The primary challenges lie in the uncertainties of measurement and understanding. The four main geospatial analytical challenges are known as the scaling problem, the boundary problem, the pattern problem and the modifiable unit-area problem. Given the challenges involved, the important considerations are discussed below only from the perspective of ecosystem accounting. Geospatial expertise should be involved in the design of spatial units and analytical methods.

2.104 Following standard statistical practice, the central element in the integration of information is the delineation of units. The units model for ecosystem accounting of basic spatial units, land-cover/ecosystem functional units and ecosystem accounting units should provide comprehensive coverage of areas within a country. While the units model constitutes a basis for integrating information, there may still be a need for different techniques (as introduced below) to be used to integrate information on ecosystem services as distinct from information on the condition of ecosystem assets. The same distinction between ecosystem services and ecosystem assets is also relevant in the scaling of data as described in section 2.5.2.

2.105 The process of characterizing the different units provides important data that may be used to aggregate and disaggregate across units. For example, a BSU may be attributed with information on standard characteristics such as area, rainfall, and elevation, in addition to being classified to a particular land-cover type. Consequently, different units of the same land-cover type may be constructed, compared and differentiated through consideration of these types of characteristics. For example, high-rainfall and low-rainfall forest may be compared with respect to their extent, condition and generation of services.

2.106 This approach is analogous to the use of units in economic statistics. Economic units, such as establishments, are commonly attributed with data on the number of people employed in addition to being classified to a particular industry. Thus, when aggregating across economic units, it is possible to consider not only the type of activity but also whether the unit is relatively large or small.

2.107 A register of BSUs containing standard information about these units could be compiled by combining remote-sensing information, administrative data on land management, and land-based surveys of land cover and land use. Spatial techniques that facilitate this integration of information include:

- Downscaling: the attribution of information from a larger area to a smaller area included within it. For example, a few 10°C bands with similar temperatures may represent average temperature for a country. A BSU existing within a given band would be attributed with the temperature range of that band. Downscaling can be further refined by using additional criteria. For example, BSUs in higher elevations may be assigned a lower average temperature.
- Overlaying: network features such as roads and rivers can be attributed to BSUs by overlaying maps of these features and recording the length of road or river that passes through the BSU, which can then be recorded in the "register".
- Aggregating: smaller features can be counted or their area added to determine the number or area within the BSU. For example, the number of people residing in a BSU can be counted if census statistics are sufficiently detailed. The total areas of residences and farms can be added up to generate a total for a BSU.

2.108 Combinations of these techniques are sometimes required to allocate between spatial units. For example, the area of a farm that crosses two BSUs may be used to allocate the wheat production between them. The effectiveness of these techniques will be enhanced if there is an availability of core measures such as land cover and locations of households, which can be used as a basis for further estimates. In some cases, modelling and expert judgement may be required.

2.109 Where data gaps exist in terms of ecological, land-use and socioeconomic data, there is the potential to use these "unit registers" to design sample surveys for ecosystem accounting purposes in which the samples take into account the different characteristics. Social surveys, business surveys and ecological field data collection could be designed to utilize these characteristics as "strata". For example, a representative sample of businesses could be drawn and stratified by LCEU type and EAU. Data collected from them on water consumption or water emissions could then be aggregated to LCEU type or EAU with some assurance of statistical rigour.

2.5.2 The scaling of data

2.110 The statistical approach described above requires a methodology for dealing with information available at different spatial scales or at only a limited number of locations. Often, a large amount of information on ecosystems comes from focused evaluations at individual sites. Therefore, in order for information to be developed for other sites or over larger areas (without conducting additional studies), it is necessary to consider how the available information may be best used.

2.111 Different approaches are available for transferring information across sites or to a broader land area: (a) *value transfer,* which involves using information from a specific study site and developing estimates for a target or policy site, as described in greater detail in chapter V; (b) *scaling up,* which involves using information from a study site and developing information for a larger area that has similar characteristics; and (c) *meta-analysis*, which is a technique for assessing a large volume of information on various study sites and integrating that information so as to produce factors that can be used to develop estimates for target areas, taking into account various ecosystem characteristics.

2.112 SEEA Experimental Ecosystem Accounting recommends that a rigorous description of statistical units following standard statistical practice be undertaken together with the application of rigorous geospatial methods before an aggregation of information to national or regional levels occurs. Using such a description of units, the application of the advancing techniques centring around value transfer may be undertaken with greater robustness and in a manner more in line with the standard approaches in official statistics (such as sampling, weighting, editing and imputation).

2.5.3 Gross and net recording

2.113 The terms “gross” and “net” are used in a wide range of accounting situations. In the SNA, the term “net” is generally used to indicate whether an accounting aggregate has been adjusted for consumption of fixed capital (depreciation). In other situations, the term is used simply to refer to the difference between two accounting items. The terms are also used to describe aggregates that have related but different measurement scopes. In the measurement of ecosystem services, the term “net” may be used to indicate that the estimates do not incorporate any double-counting which may arise owing to overlaps between areas, overlaps in the use of different methods, or overlaps due to the failure to recognize differences between final ecosystem services and underlying ecosystem processes and flows.

2.114 As far as possible, the terms gross and net are avoided in the descriptions presented in SEEA Experimental Ecosystem Accounting. This is intended to limit the potential for confusion in their use. At the same time, the general goal is to describe the relevant concepts in what might be considered “gross” terms so that all assumptions and relationships can be fully articulated. Further, compilers are encouraged to record accounting details in gross terms as much as possible and then explain any subsequent differencing of accounting entries that is used to generate estimates in net terms, which are often the focus of analysis.

2.5.4 Length of the accounting period

2.115 In economic accounting, there are clear standards concerning the time at which transactions and other flows should be recorded and the length of the accounting period. The standard accounting period in economic accounts is one year. This length of time satisfies many analytical requirements (although, often, quarterly accounts are also compiled) and also aligns with the availability of data through standard business accounts.

2.116 While one year may be suited to analysis of economic trends, analysis of trends in ecosystems may require information for varying lengths of time depending on the processes being considered. Even in situations where ecosystem processes can be analysed on an annual basis, the appropriate beginning and end of the year may well differ from the beginning and end of year that is used for economic analysis.[26]

2.117 Although considerable variation in the cycles of ecosystem processes exists, it is suggested that ecosystem accounting retain the standard economic accounting period length of one year. Most significantly, this length of time aligns with the common analytical frameworks for economic and social data; and since much economic and social data are compiled on an annual basis, the general integration of information is best supported through the use of this time frame.

2.118 Consequently, for the purposes of ecosystem accounting, it may be necessary to convert or adjust available environmental information so as to align it to a common annual basis using appropriate factors or assumptions (entailing, e.g., interpolation or extrapolation), while recognizing that data may be collected irregularly over time intervals longer than one year.

2.119 Measures of ecosystem assets should relate to the opening and closing dates of the associated accounting period. If information available for the purposes of compiling accounts for ecosystem assets does not pertain directly to those dates, then adjustments to the available data may be required. In making such adjustments and in undertaking analysis, an understanding of relevant shorter seasonal and longer natural cycles will be required. Further, it will be necessary to take into account potential time lags between measures of ecosystem condition and measures of ecosystem services. This can be done by ensuring that the appropriate time-frame is recorded along with the data on conditions and resulting services. For example, the rainfall in one calendar year may influence crop production in the subsequent calendar year.

2.5.5 Data quality and scientific accreditation

2.120 The concept of data quality for official statistics is a broad-ranging one, encompassing factors of relevance, timeliness, accuracy, coherence, interpretability, accessibility and the quality of the institutional environment in which the data are compiled. The development of frameworks, such as the ecosystem accounting framework presented here, is designed to assist in the advancement of quality, particularly in the areas of relevance, coherence and interpretability.

2.121 Commonly, data quality is associated with accuracy but accuracy is, in this regard, only one factor that needs to be considered. Given the measurement challenges faced in advancing ecosystem accounting, it is important that all factors contributing to data quality be brought forward for consideration.

2.122 In ecosystem accounting, it is likely that a reasonable proportion of the information used will be drawn from disparate data sources, possibly developed primarily to provide

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26 For example, hydrologic years may not align with calendar or financial years (see *International Glossary of Hydrology*, 2nd ed., United Nations Educational, Scientific and Cultural Organization and World Meteorological Organization, 1993).

information for administrative purposes rather than information for statistical purposes.[27] Care must therefore be taken to ensure that, as far as possible, the information is aligned with appropriate concepts and measurement boundaries.

2.123 It is also likely that information for ecosystem accounting will be drawn from scientific studies. Most information utilized for economic statistics can be confronted with related information because it is collected and analysed using the common metric of money. Scientific information often does not have a common metric and consequently assessment of relative quality may be more challenging. This being the case, it is important that scientific information be subjected to processes of peer review and accreditation to ensure that it is suitable for the purposes of ecosystem accounting. Such processes should entail assessment of the accuracy of individual indicators and pieces of information and assessment of the relevance of the characteristics, indicators and ecosystem services that are selected for use in accounting.

2.124 Compilers are encouraged to work at national and international levels to develop relevant accreditation processes for scientific and other information relevant for ecosystem accounting. In this context, it is noted that general statistical quality frameworks, such as the United Nations National Data Quality Assurance Framework, are applicable to biophysical data as well as socioeconomic data. These frameworks are tools designed to assure that data are collected and compiled according to international standards and are subject to appropriate quality assessment procedures.

2.6 Relationship of SEEA Experimental Ecosystem Accounting to the SEEA Central Framework

2.125 The SEEA Central Framework consists of three broad areas of measurement: (a) physical flows between the environment and the economy, (b) the stocks of environmental assets and changes in those stocks and (c) economic activity and transactions related to the environment. The ecosystem accounting described in SEEA Experimental Ecosystem Accounting provides additional perspectives on measurement in these three areas.

2.126 First, SEEA Experimental Ecosystem Accounting extends the range of flows measured in physical and non-monetary terms. The focus in the SEEA Central Framework is on the flows of materials and energy that either enter the economy as natural inputs or return to the environment from the economy as residuals. Many of these flows are also included as part of the physical flows recorded in ecosystem accounting (e.g., flows of timber to the economy). In addition, SEEA Experimental Ecosystem Accounting includes measurement of the ecosystem services that are generated from ongoing ecosystem processes (such as the regulation of climate, air filtration and flood protection) and from human engagement with the environment (such as through recreation activity).

2.127 The production of goods on own account (e.g., the generation of outputs from subsistence farming and fishing, the collection of firewood and water for own use, and the harvest of naturally occurring products such as berries) is within scope of the production boundary defined in the SNA and used in the SEEA Central Framework. Consequently, these flows are within the scope of the SNA benefits recorded in SEEA Experimental Ecosystem Accounting.

27 Administrative data sets are often produced and analysed with a focus on smaller or borderline cases rather than on those cases that may be the most statistically significant. Some ecological data are similarly treated. For example, water-quality data may be collected for areas where there is a known pollution problem rather than to provide broad coverage and a representative sample of water quality.

2.128 There are a number of natural inputs recorded in the SEEA Central Framework that are not recorded as part of ecosystem assets or ecosystem services. These are the inputs from mineral and energy resources, and the inputs from renewable energy sources (e.g., solar, wind and geothermal). In these cases, the inputs are not considered to arise from ecosystem processes and hence do not constitute ecosystem services. This boundary is explained in more detail in chapter III. Nonetheless, it is recommended that information on these flows be presented alongside information on ecosystem services and ecosystem assets so as to provide a more complete set of information for policy and analytical purposes.

2.129 Second, SEEA Experimental Ecosystem Accounting considers environmental assets from a different perspective than that of the SEEA Central Framework. Environmental assets, as defined in the Central Framework, "are the naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity" (para. 2.17). The scope is broader than the physical asset boundary established by the SNA, which is limited to those assets that have an economic value in monetary terms. Thus, for example, in the SEEA, all land is included regardless of value.

2.130 This broad scope encompasses two complementary perspectives on environmental assets. The focus of the SEEA Central Framework is on environmental assets in terms of individual resources (e.g., timber, fish, minerals, land). The focus of SEEA Experimental Ecosystem Accounting is on the biophysical environment as viewed through the lens of ecosystems in which the various biophysical components (including individual resources) are seen to operate together as a functional unit; thus, ecosystem assets are environmental assets viewed from a systems perspective.

2.131 Accounting for specific elements, such as carbon, or other environmental characteristics, such as biodiversity, is covered in SEEA Experimental Ecosystem Accounting but the context for specific consideration of these elements is still the biophysical environment conceived in terms of environmental assets as defined in the SEEA Central Framework.

2.132 While there is, in principle, no extension in the biophysical environment, there are some particular boundary issues that warrant consideration, particularly with regard to marine ecosystems and the atmosphere. The ocean and the atmosphere are excluded from the measurement scope of the SEEA Central Framework because the associated volumes of water and air are too large to be meaningful for analytical purposes at the country level. Their treatment in the context of ecosystem accounting is discussed in terms of statistical units for ecosystem accounting in section 2.3.

2.133 An important focus of the SEEA Central Framework is the definition of depletion of individual natural resources. SEEA Experimental Ecosystem Accounting considers measures of depletion within a broader concept of ecosystem degradation. Ecosystem degradation is a measure that covers not only the using up of resources but also declines in the capacity of ecosystems to generate other ecosystem services (e.g., air filtration).

2.134 Third, the SEEA Central Framework provides a clear outline of the types of economic activity that are considered environmental and also examines a range of relevant standard economic transactions (such as taxes and subsidies) that are relevant for environmental accounting. Further, it shows how these flows may be organized in functional accounts, the main example of which are environmental protection expenditure accounts.

2.135 For the purposes of ecosystem accounts, there are no additional transactions that are theoretically in scope since, in principle, the scope of the SEEA Central Framework covers all economic activity related to the environment, including protection and restoration of ecosystems. At the same time, SEEA Experimental Ecosystem Accounting includes a discussion on the appropriate accounting treatment for emerging economic instruments related to the management of ecosystems, through, for example, the development of markets for ecosystem services. There is no specific discussion on these types of arrangements in the SEEA Central Framework.

2.136 Finally, regarding valuation, the principles applied in SEEA Experimental Ecosystem Accounting are consistent with those of the SEEA Central Framework and the SNA. However, since many ecosystem services are not directly marketed, it is necessary to consider a range of approaches to the valuation of these services and to assess the consistency of those approaches with the concept of exchange value that underpins recording in the SNA. In the consideration of different valuation approaches, it is important to distinguish between measures of value that are based on market exchange values and those that may include consumer surplus.

Chapter III

Accounting for ecosystem services in physical terms

3.1 Introduction

3.1 The concept of ecosystem services has become central in connecting characteristics of ecosystem assets with the benefits received from ecosystems by people through economic and other human activity. As described in chapter II, ecosystem services are the contributions of ecosystems to benefits used in economic and other human activity.

3.2 The present chapter discusses a number of measurement issues related to compiling information on ecosystem services in physical terms. In this context, "physical" means "non-monetary" and measurement in "physical terms" encompasses ecosystem services that reflect flows of materials and energy, flows of services related to the regulation of an ecosystem, and flows related to cultural services. The focus of section 3.2 is on further articulating the measurement boundaries for ecosystem services. A classification of ecosystem services is introduced in section 3.3 and a basic approach to compiling accounts for ecosystem services is outlined in section 3.4. Section 3.5 provides examples of approaches to the measurement of various ecosystem services.

3.2 Measurement boundaries and characteristics of ecosystem services

3.2.1 Types of ecosystem services

3.3 Fundamental to ecosystem accounting is the recognition of the fact that a single ecosystem asset will generate a range of ecosystem services, thus contributing to the generation of a number of benefits. In some cases, the ecosystem services may be generated "in tandem", as when forest areas provide air filtration services as well as opportunities for recreation and walking. In other cases, the ecosystem services may be in competition, as when the logging of forest areas confers the benefit of provision of timber but reduces opportunities for recreation. Ecosystem accounting facilitates an examination of these trade-offs.

3.4 To support evaluation of these trade-offs, ecosystem services are grouped into different types. SEEA Experimental Ecosystem Accounting, building on a number of large ecosystem service measurement projects, employs the following three broadly agreed categories of ecosystem services:[28]

(a) *Provisioning services*, which represent the material and energy contributions generated by or in an ecosystem, for example, fishes or plants with pharmaceutical properties;

(b) *Regulating services*,[29] which result from the capacity of ecosystems to regulate climate, hydrologic and biochemical 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 relevant only in the flood zone downstream of the forest;

(c) *Cultural services*, which are generated from the physical settings, locations or situations that give rise to intellectual and symbolic benefits obtained by people from ecosystems through recreation, knowledge development, relaxation and spiritual reflection. This may involve actual visits to an area, enjoying the ecosystem indirectly (e.g., through nature movies) or the satisfaction gained from knowing that an ecosystem containing important biodiversity or cultural monuments will be preserved.

3.5 The developing Common International Classification of Ecosystem Services (CICES) provides additional detail within these broad groups. Section 3.3 presents the higher levels of an interim version of CICES.

3.6 Commonly, ecosystem services are conceptualized in terms of the types of benefits to which they contribute. In addition to distinguishing benefits as being of either the SNA or the non-SNA type (as described in chap. II), a complementary approach entails considering the private and public nature of the benefits. Three types of ecosystem services that contribute to private and public benefits can be described, based on their source:

(a) Ecosystem services that are generated from economic assets (including land and natural resources) that are privately or publicly owned and managed and which contribute to the production of private benefits (e.g., in the case of agricultural production). Private benefits are equivalent to SNA benefits as defined above;

(b) Ecosystem services that are generated from economic assets that are privately owned and managed but which contribute to the production of public benefits, that is, the benefits accrue to other economic units or to society more broadly rather than exclusively to the private owner or manager of the land (e.g., as in the case of absorption of carbon dioxide by a privately owned forest);

(c) Ecosystem services that are generated from areas that are not privately owned or managed and which contribute to the generation of public benefits (e.g., ecosystem services from public areas such as national parks and some marine areas).

3.7 Together, the second and third cases cover non-SNA benefits as described above. From an ecosystem accounting perspective, accounting in the second case is perhaps the most problematic, since here the public benefits are likely to be generated unintentionally by a private producer. The consequence is that for a given economic asset, particularly land, it becomes necessary to consider both SNA and non-SNA benefits and the ecosystem services related to each of these types of benefits. This is most relevant in accounting for ecosystems

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28 These three categories have, in broad terms, been used in the Millennium Ecosystem Assessment and The Economics of Ecosystems and Biodiversity study (TEEB) and have emerged from the project designed to develop a Common International Classification of Ecosystem Services (CICES).

29 Regulating services are also commonly referred to as “regulation and maintenance services”.

in monetary terms, for example, in the valuation of ecosystem assets, where the additional stream of benefits (in the form of public benefits) needs to be considered alongside the private values of assets that are already included in the standard national accounts.

3.2.2 Relationship between the generation and use of ecosystem services

3.8 The generation of ecosystem services is assumed to be able to be attributed to particular ecosystem assets of known spatial area. However, it is not necessarily the case that the beneficiaries or users of the ecosystem services are in the same spatial area. This is particularly true of regulating services and cultural services, where the beneficiaries may often live in large urban areas like cities while the services are generated in ecosystems located away from these areas.

3.9 Although simple assumptions regarding the location of the beneficiaries cannot be made, it is important in accounting for ecosystem services that there be attempts to determine the areas where beneficiaries are likely to be found. This information is needed for measurement purposes to ensure that changes in the population of beneficiaries are taken into account in measuring the volume of ecosystem services generated. The location of beneficiaries should also be taken into account when developing estimates of ecosystem assets, since measures of expected ecosystem service flows will be related to expected changes in populations of individuals and enterprises.

3.10 For accounting purposes, it may be useful to distinguish between the area within which the ecosystem services are generated and the areas in which they are used. This may be done by recording flows of imports and exports of ecosystem services between different areas.

3.11 The majority of provisioning services are likely to be generated and used in the same ecosystem, given the necessity for the relevant materials to be harvested in situ.[30] Subsequent transactions involving the processing, transportation and sale of harvested materials are the subject of standard economic accounting and hence are not the focus of ecosystem accounting presented here. At the same time, the linking of ecosystem accounts and standard economic accounts is facilitated through the use of the SEEA framework and hence extensions designed to analyse the relationship between ecosystem services and a more complete series of transactions, including international trade flows, may be developed.

3.12 However, while there exists (a) an awareness of the need to relate the generation of ecosystem services to the location of the beneficiaries and (b) a clear accounting logic, the measurement challenges involved indicate that testing and development of methods on an ongoing basis are still required.

3.2.3 Measurement boundaries for ecosystem services

Supporting services

3.13 Chapter II noted that the definition of ecosystem services excludes the set of flows commonly referred to as supporting or intermediate services. These include intra- and inter-ecosystem flows and the contribution of all ecosystem characteristics that are together reflected in ecosystem processes. The exclusion of supporting services ensures that the scope of ecosystem services in accounting terms reflects only the point of interaction between humans

30 This observation is also true for water: although the water itself is likely to be generated across multiple ecosystems, the provisioning service arises at the time the water is abstracted from a water body (e.g., a river or a lake) that is within a single ecosystem.

and ecosystems. Ecosystem services so conceptualized are often referred to as “final ecosystem services” in that they are the final outputs that are generated by an ecosystem. The focus on final ecosystem services helps to eliminate double-counting the contribution of ecosystem services to the production of benefits.

3.14 In theory, as illustrated in a high-level context in chapter II, it is possible to describe a series or chain of flows connecting various intra- and inter-ecosystem flows to ecosystem services and subsequently to benefits. For certain analyses, describing this chain may be particularly important for assessing the ecosystem-wide implications of specific decisions. For example, in understanding, for example, the impacts of increasing the harvest of timber from a forest. In practice, the fact that ecosystem processes are complex means that a complete and detailed accounting of supporting services is very difficult to achieve. As a consequence, the approach in SEEA Experimental Ecosystem Accounting is to account for ecosystem-wide effects through assessments of changes in the quantity and quality of ecosystem assets. At the same time, describing the chains of ecosystem flows may be important in certain situations.

3.15 Determining the final output of an ecosystem, i.e., the ecosystem services, as distinct from various supporting services, may be difficult. However, in accounting terms, the distinction is important. Without the distinction, the measurement process may aggregate ecosystem services and supporting services and consequently overstate (i.e., double count) the contribution of ecosystem services in the production of benefits. Instead, the supporting services should be seen as inputs to the generation of final ecosystem services and in this sense they are embodied in the flow of final ecosystem services into benefits.

Biodiversity and ecosystem services

3.16 As summarized in chapter II, the relationship between ecosystem services and biodiversity is complex. On the one hand, biodiversity is a core characteristic of ecosystems; on the other, changes in ecosystem extent and condition reflect changes in biodiversity.

3.17 In general, in SEEA Experimental Ecosystem Accounting, biodiversity is considered a characteristic of ecosystems rather than an ecosystem service and is therefore best accounted for as part of the assessment of ecosystem assets and, in particular, as part of the assessment of ecosystem condition. In this context, falling biodiversity (as measured, e.g., by reductions in the number of species in a given area) will generally correspond to declining ecosystem condition.

3.18 However, biodiversity may be considered an important final ecosystem service in some circumstances and the flows should be recorded as appropriate. For example, ecosystem services should be recorded to the extent that iconic species, such as the giant panda, provide cultural services.

3.19 Section 4.5 presents an extended discussion on accounting for biodiversity through a focus on the species level of biodiversity. The discussion highlights the range of information that is available in relation to biodiversity and explains the ways in which this information may be organized so as to provide information appropriate for the purposes of ecosystem accounting.

Abiotic services

3.20 As noted in chapter II, ecosystem services do not represent the complete set of flows from the environment that contribute to economic and other human activity. Important examples of other environmental flows include the extraction of mineral and energy resources from underground deposits, harnessing of energy from the sun for the growing of crops and for use as a renewable energy source, and the movement of wind and tides which can be captured to serve as sources of energy. More broadly, the environment provides the space in which economic and other human activity takes place and the provision of space may be conceptualized as an environmental flow. Collectively, these other flows from the environment are referred to as abiotic services and contribute to many SNA and non-SNA benefits. The measurement of a number of abiotic services is discussed in chapters III and V of the SEEA Central Framework.

3.21 The boundary between ecosystem services and abiotic services is defined by the scope of the processes that are relevant in their generation. It is considered that ecosystem services are generated as a result of biophysical, physico-chemical and other physical processes and interactions within and between ecosystems—that is, through ecosystem processes. Abiotic services are not generated as a result of ecosystem processes, although there may be particularly close relationships between abiotic resources and ecosystem processes.[31] It is noted that while water is an abiotic resource, its availability in the environment is considered to be a result of ecosystem processes and hence the provision of water is considered an ecosystem service.

3.22 The importance of recognizing abiotic services in ecosystem accounting is associated with the organization of information for the assessment of alternative uses of land. Most commonly, there can be trade-offs between baskets of ecosystem and abiotic services that stem from alternative land uses. These trade-offs may arise, inter alia, in cases where agricultural land is used to establish mining operations, or where roads are extended into areas of native vegetation. Analysing these trade-offs in relation only to ecosystem services would represent too narrow an approach. The consideration of both ecosystem services and abiotic services provides a more complete assessment framework and confirms the need to use the SEEA Central Framework and SEEA Experimental Ecosystem Accounting in a complementary manner.

Accounting for flows related to joint production of crops and other plants

3.23 The critical point in the chain of flows between human well-being and ecosystems for accounting purposes is the point where the ecosystem service ends and the benefit begins (see figure 2.2). In some cases, this measurement boundary can be clearly defined; but in the case of crops and other plants where there is a complex joint production process involving ecosystem services and human inputs, determining the role of inputs of ecosystem services in the production of benefits may not be a straightforward task.

3.24 The involvement of economic units in the production of crops and other plants occurs along a continuum and the extent to which the growth of these biological resources can be managed varies. Consequently, establishing standard rules by which the contribution of ecosystems can be measured is difficult. To date, two main approaches to defining a boundary for accounting purposes have emerged. The first approach, referred to here as the harvest approach, entails measurement of ecosystem services as equivalent to the amount of the crop that is harvested, irrespective of the extent of management of its growth.

3.25 The second approach recognizes the extent of management of growth by defining some crops as natural and others as cultivated, following the logic underpinning the determination of the SNA production boundary. Where crop growth is predominantly unmanaged (as is the case, e.g., for timber logged in naturally regenerated forests), the ecosystem services are equal to the amount of the crop that is harvested. Where crop growth is predominantly

31 It is also recognized that a number of resources considered abiotic, such as fossil fuels, are themselves outputs from ecosystem processes but on a quite different timescale.

cultivated, the ecosystem services comprise soil nutrient cycling, abstraction of soil water, pollination and other ecosystem processes associated with the growth of a plant that are overseen by the grower or manager utilizing other inputs (labour, produced assets, fertilizers, etc.). In both situations, the measured ecosystem service still represents the input "purchased" from the ecosystem by the grower and the ecosystem service therefore remains the final output of the ecosystem.

3.26 In ecosystem accounting, all of the following factors should be considered:

(a) In all measurement contexts, it is likely to be useful to describe the chain of flows (including intra- and inter-ecosystem flows) related to cultivated and natural biological resources to ensure a full appreciation of the ecosystem linkages, and to recognize that there are many points in the growth process where human influence may be exerted;

(b) As regards describing the chain of flows, it is likely that organizing the information according to the type of management or harvest technique being applied will be relevant. For example, the effects on ecosystem assets of the use of small fishing boats and that of large trawlers are likely to be quite different, even though the benefit extracted (i.e., fish) may be identical in both cases. Measuring changes in management and harvest technique may be an important focus of ecosystem accounting;[32]

(c) The purpose of the analysis may influence the choice of measurement approach. For broad assessments across multiple ecosystems, it may be sufficient to focus only on the harvested products, while for ecosystem specific–analysis, a different measurement focus may be more relevant.

3.27 Given the need for a measurement boundary to be drawn for accounting purposes, it is the second approach that is proposed for SEEA Experimental Ecosystem Accounting. This approach applies the SNA distinction between natural and cultivated growth processes to the measurement of ecosystem services from biological resources. Ideally, the accounts would distinguish a number of management practices so as to better reflect the different degrees of management intensity, which are, in turn, likely to have different effects on ecosystem assets.[33]

3.28 This approach provides a measurement boundary for ecosystem services that aligns with both the SNA production boundary and the boundary for the classification of natural inputs as described in the SEEA Central Framework (see sect. 3.2.2 of that publication). Importantly, the principles underlying the approach can be applied consistently across different types of cultivated biological resource (e.g., crops, orchards, livestock).

3.29 It is recognized that this approach is not consistent with many existing approaches to measuring ecosystem services, for example, the Millennium Ecosystem Assessment (MA) and The Economics of Ecosystems and Biodiversity (TEEB). In these exercises the ecosystem service boundary for crops has been equated to the crops themselves, while in the case of livestock, the approach to ecosystem services is the same as that proposed above, with those services being equal to the grass eaten. The concept underlying the principles applied in the

32 It may be especially useful to distinguish the production of crops within highly intensive systems such as greenhouses which may use few ecosystem services.

33 It should be recognized that this approach does not entail an assessment of whether the associated ecosystem may be considered natural but focuses instead on the degree to which the growth of the crop produced is more or less cultivated. Thus, the growth of wild rabbits captured in agricultural lands would be considered to be natural, that is to say, uncultivated.

approach used in MA, TEEB and other studies, encompasses the removal of biotic resources from an ecosystem rather than the SNA production boundary.

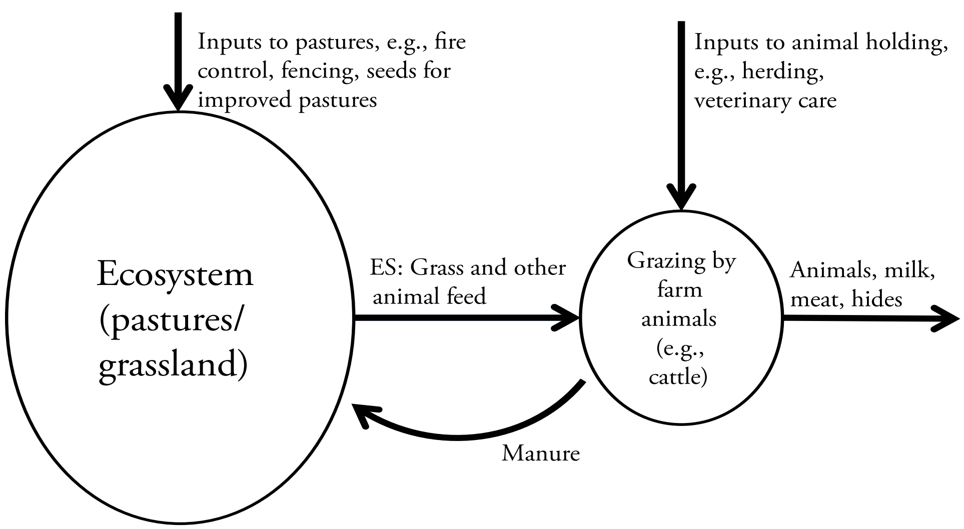
3.30 In practice, it may be difficult to articulate and measure all of the various ecosystem processes and intra- and inter-ecosystem flows for different cultivated biological resources. Hence, it may be appropriate to apply the harvest approach for cultivated crops and other plants, based on the assumption that the various flows, such as pollination, nutrients from the soil, and water, that constitute inputs into the growth of the mature crop are in fixed proportion to the quantities of harvested product. Provided that the joint production function remains relatively stable (in terms of the relative degrees of human and ecosystem involvement), this assumption may be a reasonable one.

3.2.4 Model for the measurement of ecosystem services

3.31 Building on the linkages among ecosystem assets, ecosystem services, benefits and human well-being as illustrated in the figures of chapter II, figure 3.1 presents a model that may be used to place in a specific context the measurement of ecosystem services and related flows. This model, which concerns the provision of fodder for livestock, deals with flows related to ecosystem services, benefits, human inputs and residual flows with regard to the relevant ecosystem asset (rangeland) and the associated economic activity of grazing.

3.32 Annex A3 offers further examples of the application of this model to selected provisioning, regulating and cultural services and discusses possible measurement approaches for the various ecosystem services.

Figure 3.1
Provisioning of fodder for livestock



3.2.5 Other measurement issues

Defining volumes of ecosystem services

3.33 Ecosystem services are defined as the contribution to benefits and hence should be measured only when SNA or non-SNA benefits can be identified. Thus, if there are no beneficiaries, there can be no ecosystem service flows. Consistent with this treatment, the volume of any ecosystem service will rise as the number of beneficiaries increases. For example, a walking track in a forest provides more cultural services as the number of people using the track increases. This demonstrates that the starting point for accounting for ecosystem services is the use of ecosystems in economic and other human activity.

3.34 Pursuant to this logic, in theory, there may be no ecosystem services from a given ecosystem asset during an accounting period. However, assessment of such an ecosystem asset remains relevant for three reasons. First, an ecosystem asset may have the capacity to provide ecosystem services in the future, making measures of the asset and changes therein relevant. Second, the ongoing generation of ecosystem services may be highly variable or infrequent; hence, recording no flows of ecosystem services in some accounting period may be expected. Third, although an ecosystem asset may not provide ecosystem services directly, it may contribute important inter-ecosystem flows as part of broader ecosystem processes that generate ecosystem services in other ecosystems.

"Storage" of ecosystem services

3.35 For some ecosystem services, such as those relating to the harvesting of timber or the abstraction of water, it is possible to observe the "storage" of ecosystem services for future use, as when certain natural resources available for use are not harvested during an accounting period and the available stock increases through natural regeneration or replenishment. In accounting terms, these "unused" ecosystem services are recorded within the stock of the relevant natural resources (as part of the measurement of ecosystem assets). In subsequent accounting periods, these higher levels of stock are available for future use[34] and should be recorded as ecosystem services only in the period in which they are actually generated. In effect, part of an ecosystem asset represents an inventory of natural resources that may be increased or decreased through regeneration or extraction.

Disservices

3.36 From a societal perspective, there may often be outcomes from ecosystem processes that are seen as negatives (e.g., emergence of pests and diseases). These ecosystem disservices often originate from a combination of ecosystem processes and adverse human management. In part, these disservices are included in the ecosystem accounts in an indirect manner, for example, when agricultural pests lead to declines in the condition of ecosystem assets and a reduced supply of benefits (e.g., crop production). However, other disservices that directly enter the production or consumption functions of households, enterprises and governments (e.g., the impact of natural pathogens on health) are not accounted for in the definition of ecosystem services outlined above.

3.37 At this stage, accounting for disservices and their relationship to ecosystem processes and benefits has not been developed. It is to be noted that many industries take implicit advantage of these disservices (e.g., manufacturing of pesticides and pharmaceuticals) and hence establishing the nature of the connection between any particular disservice and overall

34 Note that the pattern of growth in stocks is likely to be non-linear over time.

individual and societal well-being is likely to be difficult to establish. Also, to some extent, increases and decreases in the levels of disservice may represent normal fluctuations in ecosystem processes and perhaps might best be reflected in accounting for changes in ecosystem assets. Overall, more work is required to understand and account for disservices within the ecosystem accounting framework presented here.

Scale

3.38 The scale of measurement required to assess the generation and use of ecosystem services will vary by type of ecosystem service. Some may be generated in a very small area, whereas others may be generated over areas that are quite large. Hence, the concept of the generation of services "from an ecosystem" may be interpreted in different ways depending on the ecosystem service under consideration. For measurement purposes, it is recommended that particular attention be paid to the formation of meaningful spatial units (as discussed in chap. II), as this will provide a means of managing issues of scale and coverage systematically.

Flows of ecosystem services between countries

3.39 There are a number of factors to be taken into account when considering flows of ecosystem services between countries. First, there are some regulating services, for example, carbon sequestration, whose provision provides benefits to all people, irrespective of the location of the relevant ecosystem. From an accounting perspective, it would be possible in this case to record imports and exports of ecosystem services so as to reflect the distinction between the generation of the service and the location of the beneficiaries. Similar, but smaller-scale, transactions between neighbouring countries might be recorded in relation to air filtration and water purification services.

3.40 Second, non-residents visiting a country are likely to use its ecosystem services and, similarly, residents visiting another country are likely to use ecosystem services provided by the country visited. These flows of ecosystem services may be recorded as imports and exports of ecosystem services, as appropriate. A related situation concerns provisioning services from fish caught by resident producers in non-resident waters. These services should be treated as imports of an ecosystem service in the accounts of the country undertaking the fishing.

3.41 Finally, it is to be noted that there are likely to be inter-ecosystem flows that cross country boundaries. Flows of water through major rivers are a particular example. As described, inter-ecosystem flows are not recorded as flows of ecosystem services; however, these flows should be considered part of a complete accounting for ecosystem assets. For accounting purposes, they may be identified separately from inter-ecosystem flows within a country but the overall conceptual treatment is analogous.

3.3 Classification of ecosystem services

3.42 The classification of ecosystem services described in SEEA Experimental Ecosystem Accounting—the Common International Classification of Ecosystem Services (CICES)—is aligned with the discussion on measurement boundaries and characteristics of ecosystem services described in section 3.2. CICES fits into the broader framework of ecosystem accounting by providing a structure for classifying those flows defined as ecosystem services. It does not provide a structure for classifying ecosystem assets, ecosystem processes, ecosystem characteristics, abiotic services or benefits. Figure 2.3 in chapter II places all of these elements of ecosystem accounting in context.

3.43 At the broadest level, three different categories of ecosystem services are distinguished in SEEA Experimental Ecosystem Accounting: (a) provisioning services; (b) regulating services; and (c) cultural services, as defined in section 3.2.

3.44 Table 3.1 presents the higher levels of CICES and experience to date suggests that at these broad levels the structure of CICES can be used in a range of situations. The table also provides examples of ecosystem services that are considered to be within each group without attempting to be exhaustive. Examples of related benefits are also shown in the final column.

Table 3.1
Three levels of the Common International Classification of Ecosystem Services (CICES)

CICES for SEEA Experimental Ecosystem Accounting				
Section (1-digit)	Division (2-digit)	Group (3-digit)	Examples of ecosystem services	Examples of benefits
Provisioning	Water	Water	Water taken up for the growing of crops and animals, agricultural, mining, manufacturing and household use, etc.	Drinking water, water for crop production, livestock feed, thermoelectric power production, etc.
	Materials	Uncultivated terrestrial plants and animals for food	Uncultivated terrestrial plants and animals (e.g., game animals, berries and fungi in the forest) taken up for food	Food for human consumption
		Uncultivated freshwater plants and animals for food	Uncultivated freshwater plants and animals (e.g., plaice, sea bass, salmon, trout) taken up for food	Food for human consumption
		Uncultivated marine plants, algae and animals for food	Uncultivated marine plants, algae and animals (e.g., seaweed, crustaceans such as crabs, lobsters, crayfish) taken up for food	Food for human consumption
		Nutrients and natural feed for cultivated biological resources	Nutrient resources for uptake by crops, fodder for livestock, feed for aquaculture products	Crops and vegetable products, cultivated timber and cotton, cattle for meat and dairy products, aquaculture products
		Plant and animal fibres and structures	Plant and animal fibres and structure (e.g., natural timber, straw, flax, skin, bone, algae) to be harvested for manufacturing or domestic use	Logged timber, straw, flax, algae, natural guano, corals, shells, skin and bone for further processing in the manufacturing industry (e.g., fertilizer and chemicals) or final consumption
		Chemicals from plants and animals	Substances and biochemicals (e.g., rubber, enzymes, gums, oils, wax, herbal substances) from living organisms taken up for medicinal use, manufacturing or domestic production	Substances and biochemicals, such as rubber, enzymes, gums, oils, wax, herbs for cosmetic and medicinal use or for further processing in the manufacturing industry
		Genetic materials	Genetic materials taken up for breeding programmes (e.g., for crop plants, farm animals, fisheries and aquaculture)	Genetic materials used for breeding programmes (e.g., for crop plants, farm animals, fisheries and aquaculture)
	Energy	Biomass-based energy	Wood taken up for fuel; uncultivated energy plants, algae to be harvested for biofuel; dung, fat, oils from natural animal to be extracted for energy	Heating, light, fuel, etc.
	Other provisioning services	Other provisioning services, n.e.c.	Other provisioning services that are not classified elsewhere in this section, such as provisioning of exotic animals, tamed animals trained to harness	Work and pet animals
Regulating	Remediation and regulation of biophysical environment	Bioremediation	Chemical detoxification/breakdown of pollutants by plants, algae, microorganisms and animals	Reduced level of pollutants/contaminants in soil and groundwater
		Dilution, filtration and sequestration of pollutants	Dilution of municipal waste-water in rivers, removal of organic materials and nutrients from waste-water by biogeochemical process, filtration of particulates and aerosols, sequestration of nutrients and pollutants in organic sediments, removal of odours	Cleaner air, water and soil

Section (1-digit)	Division (2-digit)	Group (3-digit)	Examples of ecosystem services	Examples of benefits
Regulating (cont'd.)	Flow regulation	Air flow regulation	Natural or planted vegetation that serves as shelter belts, air ventilation services	Dust storm mitigation, shelter from the wind, improvement of ventilation and heat mitigation in urban areas
		Water flow regulation	Regulation of timing and magnitude of water run-off, flooding and aquifer recharge	Prevention of flood damage, recharge of water into surface water and groundwater, reduced damage from high water levels
		Mass flow regulation	Stabilization of soil and mudflows	Prevention of soil erosion, avalanches and mudflows
	Regulation of physico-chemical environment	Atmospheric regulation	Capture of carbon dioxide, climate regulation, maintenance of urban climate (such as temperature and humidity) and regional precipitation patterns	Reduced amount of greenhouse gases in the atmosphere, reduced impact of climate change, improvement of climate conditions
		Water cycle regulation	Oxygenation of water, retention and translocation of nutrients in water	Improvement of water quality
		Pedogenesis and soil cycle regulation	Maintenance of soil fertility and structure in the cultivated system	Improvement of soil fertility and productivity in the cultivated system
		Noise regulation	Natural buffering and screening	Reduction of noise level
	Regulation of biotic environment	Life-cycle maintenance, and habitat and gene pool protection	Pollination, seed dispersal, maintenance of habitat nursery population and habitats	Improvement of productivity of crops, habitats conservation
		Pest and disease control (including invasive alien species)	Control of pathogens	Reduced hazard level to crops, human health and the environment
Cultural	Physical or experiential use of ecosystems [environmental setting]	Non-extractive recreation	Landscape and seascape character and biodiversity of species for hiking, birdwatching, recreation	Enjoyment from hiking, birdwatching, whale watching, etc.; increased health level; increased number of visitors in the tourism industry
		Information and knowledge	Landscape character and biodiversity of species for scientific research and education	Scientific progress (e.g., such as in pollen record, tree ring record, genetic patterns); increased knowledge (e.g., subject matter for wildlife programmes and books), etc.
	Intellectual representations of ecosystems [of environmental settings]	Spiritual and symbolic	Landscape character and biodiversity of species of cultural heritage values, sense of personal and group identity (sense of place), spiritual and religious function, etc.	Increased sense of personal and group identity, national symbols, performance of spiritual and religious functions
		Non-use	Ecosystem capital for future generation of ecosystem services	Availability of biodiversity and ecosystem services to future generations

3.45 There are three important boundaries in relation to CICES:

(a) First, abiotic services are excluded. Where relevant for analysis, estimates of these flows may be appended to presentations showing ecosystem services;

(b) Second, supporting services are excluded. There is no attempt in CICES to provide a classification that covers all of the possible intra- and inter-ecosystem flows that would need to be incorporated. It is recognized that many of the regulating services may also be considered supporting services depending on their place in the chain of ecosystem flows. Indeed, CICES is a classification of those flows that have been defined as "final" ecosystem services and hence should be used only to classify those flows;

(c) Third, consistent with the proposals set out in section 3.2, in the case of cultivated crops and other plants, the "final" ecosystem services are not the crops or other harvested products. Rather, they are flows related to nutrients, water and various regulating services, such as pollination. (Note that in the case of uncultivated and natural crops and other plants, the ecosystem services are measured by the harvested products.)

3.46 If a choice is made to use an alternative boundary for the measurement of ecosystem services related to crops and other plants, then an alternative application of CICES would be required. For example, if ecosystem services are measured using flows of harvested crops, then it is necessary to exclude flows relating to the growth of these plants, such as pollination and abstraction of soil water. Put differently, both pollination and harvested crops should not be combined in a measure of "final" ecosystem services, as this would represent a "double count" in accounting terms.

3.47 Another way of viewing the potential double-counting issue is to consider the measurement of ecosystem services from the perspective of beneficiaries—that is, the economic and social entities (enterprises, households, governments) that receive the contributions from ecosystems. Ecosystem contributions are embodied in benefits (see figure 2.3) and for each benefit there must be a beneficiary. Thus, to be included in the measurement scope of ecosystem services, there must be a direct contribution to an enterprise, household or government unit.

3.48 By considering the measurement scope in this way, a large number of ecosystem flows are excluded, in particular flows within and between ecosystems. These intra- and inter-ecosystem flows may be fundamental to the operation and condition of ecosystems (e.g., pollination of wild plants and wild deer drinking water from a lake) but if there is no direct contribution to households, government units or enterprises, ecosystem services should not be recorded.

3.49 Unfortunately, from the perspective of the classification of ecosystem services, it is not the case that ecosystem services can be neatly classified between those that contribute directly to economic and social beneficiaries and those that are directly beneficial to ecosystems. For example, when a household abstracts water from a lake and a wild deer drinks from the same lake, the ecosystem flow of the provisioning of water is the same.

3.50 A similar situation arises in economic statistics. The classification of products (e.g., following the international standard Central Product Classification (CPC)) includes, appropriately, a large number of products that may be considered intermediate or final depending on the beneficiary. For example, the purchase of bread is considered final if purchased by a household but intermediate if purchased by a restaurant. However, the CPC appropriately contains only one product, bread, rather than two (or more) products.

3.51 Given this situation, CICES and other classifications of ecosystem services, must be used in conjunction with an understanding of the beneficiaries that are within scope of the measurement concept. Without clearly defining the beneficiaries, there is likely to be an overestimation of the quantity of ecosystem services by adding together the intra- and inter-ecosystem flows that reflect the operation of an ecosystem, and the "final" ecosystem services that are direct contributions to economic and social beneficiaries.

3.52 The link between CICES and beneficiaries is shown in table 3.2. In this table the types of services (shown by CICES section) are cross-tabulated with beneficiaries (enterprises, households and government) and with ecosystems. The table demonstrates that where a link exists between the type of ecosystem service and a beneficiary (i.e. an economic unit) these flows should be recorded as ecosystem services for accounting purposes. However, where the recipient is an ecosystem, the SEEA EEA proposes recording these flows as intra- or inter-ecosystem flows.

Table 3.2
Beneficiaries and the classification of ecosystem services and intra- and inter-ecosystem flows

Types of ecosystem services (by CICES)	Beneficiaries			Ecosystems
	Enterprises	Households	Government	
Provisioning Regulating Cultural	Recorded as "Final" Ecosystem services			Recorded as Intra- and inter-ecosystem flows

3.53 The version of CICES shown in table 3.1 is an interim version. CICES is under ongoing development and review to enable a full articulation of relevant classes, a description of the various levels including resolution of boundary issues, and an alignment to fit within general requirements for statistical classifications.[35] The further development of CICES will benefit from testing and use in the compilation of estimates of ecosystem services.

3.4 Accounts in physical terms for ecosystem services

3.4.1 Introduction

3.54 The aim of accounting for ecosystem services is to organize information on the flows of ecosystem services by type of service, by ecosystem asset, and by economic units involved in generating and using the various services. This section describes relevant measurement issues including statistical units, the structure of tables and possible extensions, links to the SNA and the SEEA Central Framework, and approaches to aggregation.

3.55 Following the units model outlined in section 2.3, a useful starting point for the measurement of individual ecosystem services is likely to be found at the level of the LCEU. For many ecosystem services, this approach is appropriate, since many ecosystem services will be generated within the spatial area defined by an LCEU.

3.56 Where an LCEU is completely contained within an EAU, no attribution of observed physical flows to finer spatial levels, that is, to that of the BSU, is required for reporting at the EAU level. However, where a particular ecosystem service is generated over an area that crosses LCEU and EAU boundaries, attribution of information to finer spatial levels, such as that of the BSU is likely to be required in order to permit attribution to the EAU level.

3.57 The process of attributing information to the BSU may require particular assumptions, scientific knowledge or other information. Consideration of the discussion on integrating information across spatial scales in section 2.5 is likely to be relevant. This is an area of ecosystem accounting where further testing and development of methods are required.

3.4.2 Measurement units for ecosystem services

3.58 The measurement units used for recording flows of ecosystem services will vary significantly by type of ecosystem service. Provisioning services will generally be measured in units, such as tonnes or cubic metres, that reflect the relevant physical properties of the underlying input. However, they may also be measured in units specific to the type of service.

35 Materials relating to the development of CICES and to the classification of ecosystem services are listed in the references.

For example, biomass-based energy may be measured in joules. All measures should reflect the total flows of the ecosystem service over an accounting period, which is usually one year.

3.59 Regulating services will also be measured in a variety of units depending on the indicator used to reflect the flow of service. For example, the service of carbon sequestration would normally be measured in tonnes of carbon sequestered.

3.60 Cultural services are likely to be measured in units related to the people interacting with the ecosystem and using the ecosystem service. Possible measurement units include the number of people visiting a site or the time spent using the service. Also, since the volumes of cultural services are likely to be related to the quality of the ecosystem, it may be relevant to take into account changes in ecosystem condition and ecosystem characteristics. For example, visits to national parks may be linked to the general condition of the associated ecosystems.

3.61 For presentational purposes, it may be relevant to convert all of the measures into index form with a common reference year set equal to 100. Then a focus may be placed on increases or decreases in flows of ecosystem services over time. However, such a presentation might suggest implicitly that each ecosystem has equal weight; hence, the relative significance of each service would be unclear.

3.4.3 Possible tables for ecosystem services

3.62 The basic table presented below can be used to record estimates of the physical flows of different ecosystem services. It may be best to envisage the construction of this table for a country as a whole (the highest level of the EAU), which is composed of numerous LCEUs of different types. Thus, it is assumed in the table that the same type of LCEU in different parts of a country can be aggregated. It is also assumed that all ecosystem services are attributable to specific types of LCEU, which is likely to be appropriate for many provisioning and cultural services but not for some regulating services (e.g., water flow regulation).

3.63 No row in table 3.3 is included to reflect a total flow of different ecosystem services, since the aggregation of estimates across different services is not a straightforward undertaking and is subject to a considerable number of caveats. The following subsection discusses relevant approaches and concerns.

Table 3.3
Physical flows of ecosystem services for an EAU

	Type of LCEU				
Type of ecosystem services (by CICES)	Forest tree cover	Agricultural land[a]	Urban and associated developed areas	Open wetlands	…
Provisioning services	For example, tonnes of timber	For example, tonnes of wheat			
Regulating services	For example, tonnes of CO_2 stored/released	For example, tonnes of CO_2 stored/ released	For example, tonnes of CO_2 stored/released	For example, tonnes of phosphorus absorbed	
Cultural services	For example, number of visitors and hikers		For example, hectares of parkland	For example, hectares of habitat for ducks	

a Medium to large fields of rain-fed herbaceous cropland.

3.64 By definition, the total generation of a single ecosystem service should equal the total use of that service. However, the uses of the services generated within a single EAU may not all take place within the EAU. For example, urban areas will benefit from the air filtration services provided by nearby forests. It may therefore be of interest to further disaggregate the information on the use of ecosystem services by spatial area distinguishing between those services that are used by people within the EAU and those used by people outside the EAU.

3.65 The attribution of the generation of ecosystem services to type of economic unit (e.g., enterprises, households, government) will require certain assumptions regarding the nature of the ownership and management of the areas within the EAU in relation to the various ecosystem services. Table 3.4 presents one way of organizing information on the generation and use of ecosystem services by economic units. The measurement of these flows may be of particular relevance in accounting for ecosystem degradation.

Table 3.4
Generation and use of ecosystem services for an EAU

Type of ecosystem services (by CICES)	Generation of ecosystem services					Use of ecosystem services				
	Enterprises	Households	Government	Rest of the world	Total	Enterprises	Households	Government	Rest of the world	Total
Provisioning services										
Regulating services										
Cultural services										

3.66 A full articulation of ecosystem services flows requires consideration of flows to and from the rest of the world, which are of two main types. First, there are ecosystem service flows between countries where the generation of ecosystem services is in one country while the beneficiary (not necessarily the sole beneficiary) is located in another country. For example, a forest located on a national border may provide air filtration services to people living in both countries.

3.67 Second, there are ecosystem service flows generated within a country by both residents and non-residents where non-residents include people travelling for business or pleasure, or enterprises located temporarily in a different country. Following the structure of the standard economic accounts, ecosystem services generated outside the economic territory may be considered imports and those generated within the economic territory but consumed by non-resident beneficiaries may be considered exports.

3.68 Table 3.4 includes both of these types of flows between countries and their resident economic units under the column headings entitled "Rest of the world". Ideally, these different types of flows should be distinguished. It may also be useful for analytical purposes to determine what proportion of the ecosystem services used by domestic economic units (enterprises, government, households) is supplied by the rest of the world. Note that ecosystem services that are embodied in traded products, for example, provisioning services embodied in imports and exports of timber, should not be recorded in this table. The ecosystem services flow recorded in this instance is from the ecosystem to the enterprise undertaking the logging activity. Subsequent flows of products are recorded elsewhere in the accounting frameworks, e.g., in supply and use tables.

3.69 Depending on the purpose of analysis, it may be relevant to also include measures of abiotic services for particular spatial areas (the EAU or the LCEU). The joint presentation of information on ecosystem services and abiotic services may facilitate a greater understanding of the trade-offs in the management of given areas of land.

3.70 Information organized following the broad structure in table 3.4 may be compared directly with information on economic activity organized following the standard economic accounts. For example, information on the use of ecosystem services by enterprises may be compared directly with measures of intermediate consumption and output of enterprises, possibly classified by industry. Estimates of use of ecosystem services by households can be directly compared with estimates of household final consumption expenditure. Recalling that ecosystem services are contributions to benefits, it may also be of analytical interest to assess the extent to which the SNA benefits embody ecosystem service inputs by aligning information by type of ecosystem service with specific products from the standard economic accounts. Finally, measurement of the generation and use of ecosystem services provides a starting point for integrating these flows within a sequence of accounts, since these flows can be considered extensions to the standard production account of the SNA. Such extensions are described in more detail in chapter VI.

3.4.4 Approaches to aggregation of ecosystem services

3.71 In the context of ecosystem accounting, aggregation involves bringing together information about a particular spatial area so as to provide overall measures of flows of ecosystem services. Three different forms of aggregation can be envisaged: aggregation of the various ecosystem services within a spatial area (e.g., within an EAU); aggregation of a single ecosystem service across multiple spatial areas within a country (e.g., across multiple LCEUs); and aggregation of all ecosystem services across multiple (potentially all) areas within a country.

3.72 Before considering methodological issues in aggregation, compilers should carefully consider the purpose of aggregation across different types of ecosystem services. Since some ecosystem services are competing and some are produced in tandem, it may be sufficient to present information on flows of different ecosystem services to allow analysis of trade-offs without undertaking aggregation.

3.73 Where aggregation of different ecosystem services is undertaken, it is necessary to aggregate flows for each service that are likely to be recorded using different measurement units. In this case, some assumptions will be required regarding the relative importance or significance of each ecosystem service, which can be formulated through establishing weights that reflect the relative importance of each service.

3.74 There are a number of possible means of determining weights for ecosystem services. One option is to assume that each service has equal weight. Another is to calculate a price in monetary units for each service (see chap. V for a discussion of this issue). A third alternative is to derive weights based on a common "currency", for example, hectares or units of carbon, through conversion of different physical measures into a common measurement unit.

3.75 Either of two methods for deriving aggregate measures using a set of weights may be adopted. The methods are distinguished by the type of weights being used. The first method involves the construction of a composite index. This requires converting all physical flow measures to index numbers representing the changes between two periods (generally the first period is set equal to 100). Then, all numbers in a period are multiplied by the relevant weight to produce an average index number value for that period. In the first or base period, the average will be equal to 100. In effect, different levels of significance are applied to the different rates of change in the various service flows.[36]

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36 Additional details on the compilation of composite indicators are provided in an Organisation for Economic Co-operation and Development/Joint Research Centre handbook.

3.76 The second method involves the summation of measurement observations that have been converted to a common unit of measure. For example, prices can be used to convert physical measures to monetary values; the monetary values of the services can then be summed to provide an aggregate measure.

3.77 Clearly, the derivation of aggregates involving a number of different ecosystem services is heavily dependent on the choice of weights. Without a robust rationale for choosing a particular set of weights, the ability to interpret the resulting aggregates will be limited. It is possible to test the robustness of the weights themselves through sensitivity analysis (i.e., testing the variations in aggregate values in response to variations in the weighting patterns). However, this should not be viewed as a substitute for grasping the conceptual implications of choosing a particular weighting structure. This caveat is especially applicable to the case where the use of prices is being considered, given the conceptual and practical complexities of valuation, as described in chapter V.

3.78 Aside from the selection of weights, there is another significant issue associated with aggregation across different ecosystem services, namely, the extent to which the ecosystem services measured provide complete coverage of all relevant ecosystem services. Indeed, as regards the interpretation of aggregates, inadequate coverage may be a more significant issue than the selection of weights.

3.79 The aggregation of the same ecosystem service across multiple ecosystems will not generally require dealing with different measurement units. However, there are measurement challenges relating to the extent to which an ecosystem service can be considered to be of a consistent character and quality across different spatial areas. If an ecosystem service has been measured in each area and is considered to be of consistent quality, then aggregation is straightforward. Often, however, in ecosystem services measurement, it is necessary to estimate flows of ecosystem services using data from various sites and to then use scaling and transfer techniques (discussed in chap. II) to provide estimates for other areas. In these cases, it is assumed that differences in the quality of ecosystem services between areas will be taken into account by adjusting for any variations in ecosystem characteristics.

3.80 The aggregation of ecosystem services across different services and multiple spatial areas should take into consideration the issues of weights, scaling and transfers which have been described above.

3.5 Measuring ecosystem services

3.81 The present section provides a general discussion on the measurement of ecosystem services in physical terms, including some consideration of which ecosystem services may be the focus of measurement, given that it is unlikely to be possible to identify and define all ecosystem services. Annex A3 to the present chapter, which describes potential approaches to the measurement of a range of ecosystem services in physical terms (see table 3.5 below for a list of ecosystem services covered therein) was created to assist compilers who are commencing work in measuring ecosystem services including through a more extensive examination of the measurement concepts.

Table 3.5
List of selected ecosystem services as described in annex A3

Type of ecosystem services	Description	Corresponding benefit
Provisioning services		
Services for crop production	Abstraction of soil water, nutrient uptake, pollination for the growing of crops, etc.	Crops can be consumed directly or further processed
Fodder for livestock	Rangelands provide fodder (grass, herbs, leaves from trees) for livestock	Livestock products (including animals, meat, leather, milk)
Raw materials, including wood and non-timber forest products	Ecosystems, in particular forests, generate stocks of wood and non-timber forest products which may be harvested. Non-timber forest products include, for instance, rattan, various food products, genetic materials, ornamentals and pharmaceuticals	Firewood, logged timber, non-timber forest products
Fish and other aquatic and marine species from marine and inland waters	Marine and other aquatic ecosystems provide stocks of fish and other species which can be harvested	Fish and other species can be consumed or further processed
Water	Water that is filtered and stored by ecosystems can be used as raw material for the production of drinking water or in other economic activities (e.g., irrigation)	Drinking water
Regulating services		
Carbon sequestration	Ecosystems sequester and store carbon	Climate regulation
Air filtration	Vegetation can filter particulate matter from ambient air	Cleaner air
Flood protection	Ecosystems regulate river flows and can provide a barrier against floods	Protection of properties and lives
Cultural services		
Providing opportunities for tourism and recreation	Ecosystems provide physical space and landscape features, enabling people to enjoy landscape views or undertake activities such as hiking and cycling	Recreational benefits

Provisioning services

3.82 It is provisioning services that should be the most amenable to measurement, as many of the indicators relate to currently measured aspects of economic activity. At the same time, defining the boundary for cultivated crops and other plants means that a range of additional information may be required in order to enable measurement of flows related to these cultivated resources.

Regulating services

3.83 Typically, regulating services involve a process regulated by the ecosystem which provides a non-SNA benefit to society and individuals in the form of a lowering of the risks of certain negative outcomes (such as polluted air). However, typically for this category of services, a range of conditions and factors need to be in place before a benefit is received. Thus, the processes regulated by the ecosystem generate a benefit—and therefore an ecosystem service—only in situations where the ecosystem processes affect people. For instance, air filtration by vegetation materializes as an ecosystem service only if there is air pollution in the atmosphere that is being absorbed by the vegetation *and* if there are people living nearby who benefit from a lower concentration of air pollutants.

3.84 These other conditions and factors, which differ among the various regulating services, are not, typically, characteristics of an ecosystem and are not reflected in measures of ecosystem assets. Nevertheless, they need to be understood and quantified before physical and monetary measurement of the ecosystem services can take place.

3.85 The delivery of regulating services is commonly and increasingly affected by land-use choices made by economic units and society generally. At a local level, the delivery of regulating services may be affected negatively by the removal of vegetation, for example. Equivalently, the delivery of regulating services may be enhanced by the planting of vegetation or the protection of existing vegetation. Thus, while the regulating services themselves are generated from ecosystem processes, the extent of their delivery can be materially affected by human activity.

Cultural services

3.86 Cultural services are generally more difficult to define than provisioning and regulating services, since they reflect the nature of human interactions and relationships with ecosystems rather than more direct extraction of resources or use of ecosystem processes. At the same time, there are some cultural services that represent direct contributions to economic activity, particularly the opportunities provided by ecosystems for the production of tourism and recreation services. Also, the assessment of some cultural services will be implicit in the values placed on landownership, for example, the amenity value of a scenic view. Thus, there may be a range of cultural services for which information is available based on data about various activities and the outlay of expenditures.

3.87 For other cultural services, the aim is to measure the amenity or utility that people derive from the landscape. For many people, particularly indigenous peoples, this may be strongly spiritual and cultural. In general terms, the extent of these services will be a function of human access to the ecosystem (perhaps based on the number of people interacting with the ecosystem, either directly or remotely) and the extent and quality of the ecosystem and the surrounding landscape.

Setting priorities for measurement of ecosystem services

3.88 In piloting ecosystem accounting at the national scale, it may be most feasible initially to select a limited rather than a comprehensive set of ecosystem services for inclusion in ecosystem accounting exercises. The potential feasibility of measuring ecosystem services at the national scale, in both physical and monetary terms, differs strongly among different ecosystem services. These differences occur owing to differences in data availability, the methodology constructed, and the complexities related to scaling up and aggregating physical and monetary units associated with ecosystem services. In addition, there may be different policy priorities influencing the analysis of certain ecosystem services.

3.89 To facilitate the process of selecting ecosystem services in ecosystem accounts, a list of criteria for ranking ecosystem services with regard to their potential suitability for inclusion in ecosystem accounting is presented in table 3.6 below. The applicability of the criteria will differ among countries and the list should be seen only as indicative.

3.90 As environmental concerns, data availability and policy contexts will differ in each country, the selection of ecosystem services for ecosystem accounting will differ as well. In general, from a methodological and data perspective, provisioning services, including water supply, are often the most feasible focus for ecosystem accounting, since the benefits arising from these ecosystem services are generally measured as part of standard economic accounts. While measurement of provisioning services may be a useful means of understanding the relative dependence of economic activity on ecosystems, broadening the range of measurement and gathering information on regulating and cultural services, whose significance may not be reflected at all in standard economic statistics, are the source of an additional value of ecosystem accounting

Table 3.6
Criteria for the prioritization of ecosystem services for accounting purposes

	Criterion	Brief explanation
Environmental concerns		
1	Sensitivity of the service to changes in the environment, including from anthropogenic stressors	Consideration may be given to services that are sensitive to environmental change and/or clearly reflect changes in natural capital stocks
2	Likelihood of irreversible loss of ecosystem services, including through the supplying ecosystem's being pushed past a significant threshold and out of its "safe operating range"	Consideration may be given to services, generated from ecosystems, that are generally understood to be operating close to significant environmental thresholds
Policy context		
3	Possibility of influencing environmental and/or economic policy and decision-making (decision-making context)	Consideration may be given to services that can be easily influenced, relatively speaking, by decision-making to enable maximum relevance for policymaking
4	Economic importance of the ecosystem service	Consideration may be given to those services that generate the highest economic benefits
Data and methods		
5	Availability of broadly accepted methods for analysing ecosystem services supply in physical terms at a high level of aggregation	Consideration may be given to services for which broadly accepted modelling and/or quantification techniques are available
6	Availability of broadly accepted methods for analysing ecosystem services supply at a high level of aggregation in monetary terms	Consideration may be given to services for which broadly accepted valuation approaches are available
7	Availability of data for measuring ecosystem services in physical terms	Producing national-level accounts will often require scaling up estimates of ecosystem services to that level based on underlying spatial data. Both point-based and spatially explicit data (e.g., on land cover, soils, water tables, ecosystem productivity) are required to analyse a service at the national level
8	Availability of data for measuring ecosystem services in monetary terms	
9	Plans to generate new data on ecosystem services supply	A firm intention to ensure, or a high likelihood, that new environmental monitoring will provide essential data

3.91 As part of the effort to broaden the coverage of ecosystem services, a particular focus on the measurement of the two areas of water and carbon might be considered. Data on water resources is often available, in particular regarding the abstraction of water for drinking and other purposes. However, the link between ecosystem management and water provisioning is less clear-cut, in respect, for example, of such processes as water purification in aquatic ecosystems, water storage in ecosystems in upper watersheds. Given the economic importance of water supply, and the pressure on water resources in many parts of the world, including this service in ecosystem accounts may be a priority in many countries. A challenge is to better understand, in particular at high levels of aggregation, the infiltration, purification and storage processes involved. The incorporation of measures relating to water within ecosystem accounting is significantly aided by the development of international standards on accounting for water presented in *System of Environmental-Economic Accounting for Water (SEEA-Water)* (United Nations, 2012a) and the companion guidelines, *International Recommendations for Water Statistics* (United Nations, 2012b).

3.92 Recent years have seen a strong increase in interest in the carbon-related ecosystem services of carbon sequestration and the storage of carbon. There is a large amount of ongoing research aimed at quantifying these services at different scales, from local processes to national stocks and flows. The development of market mechanisms related to the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD) means that, increasingly, there is also information available on markets related to carbon. Given the broad interest and the increasing availability of methods and data relevant to these services, there is a high potential for their inclusion in ecosystem accounts.

3.93 One challenge posed by these ecosystem services is to account for both the storage and the sequestering of carbon. Storage and sequestering are not equivalent sevices. A high carbon stock may mean that sequestration is limited because the vegetation is close to its maximum biomass under the ecological conditions pertaining in the particular area. A low carbon stock may mean that there is scope for additional sequestration (e.g., in a recently cut forest with intact soil fertility), although (e.g., as in the case of desert) not necessarily.

3.94 It should be noted, however, that although scientific methods and data are relatively well developed for this service, the same cannot be said of all ecosystems. While there is relatively much data available for forests, relatively little data exists for lakes and coastal systems. There may also be data and/or methodological constraints related to analysing carbon sequestration in degraded forests and in forest or landscape mosaics. Further discussion relating to accounting for stocks and flows of carbon is presented in chapter IV.

Annex A3

Models for the measurement of selected ecosystem services

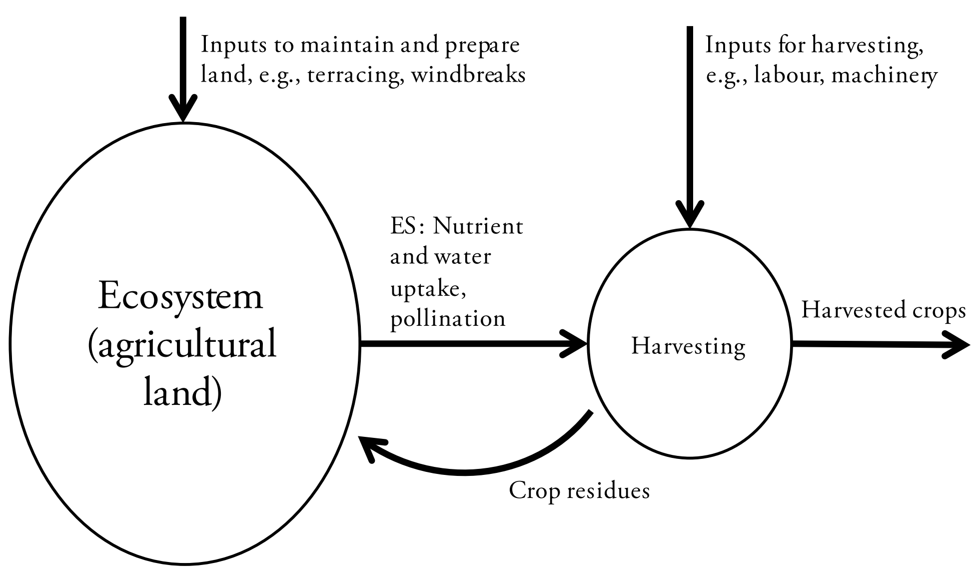
A3.1 The present annex provides examples of measurement approaches for some selected ecosystem services. It is recognized that deconstructing the information in this way may give the impression that ecosystem services are easily separable flows. However, in theory, the measurement of ecosystem services should be based on a holistic approach encompassing the entire ecosystem, with the emergent services treated as a bundle. Unfortunately, as direct measurement of this bundle is not feasible, statistically or scientifically, a component-based approach must be adopted.

Provisioning services

Provisioning services for crop production

A3.2 Crop production includes the production of annual and perennial crops on cultivated land, including plantations (see figure A3.1). The ecosystem services associated with crop production include pollination, abstraction of soil water, and soil nutrient uptake and fixation. The farmer or land manager (a) manages, on a regular basis, the overall production environment, that is, the farm or plantation, for instance, by constructing windbreaks or irrigation reservoirs, pruning; and (b) harvests crops using labour and machinery. In practice, it may not always be easy to distinguish the relevant importance of these different inputs at an individual-farm level. Crop residues are recorded as remaining in the field and returned to the ecosystem (a type of intra-ecosystem flow).

Figure A3.1
Crop production

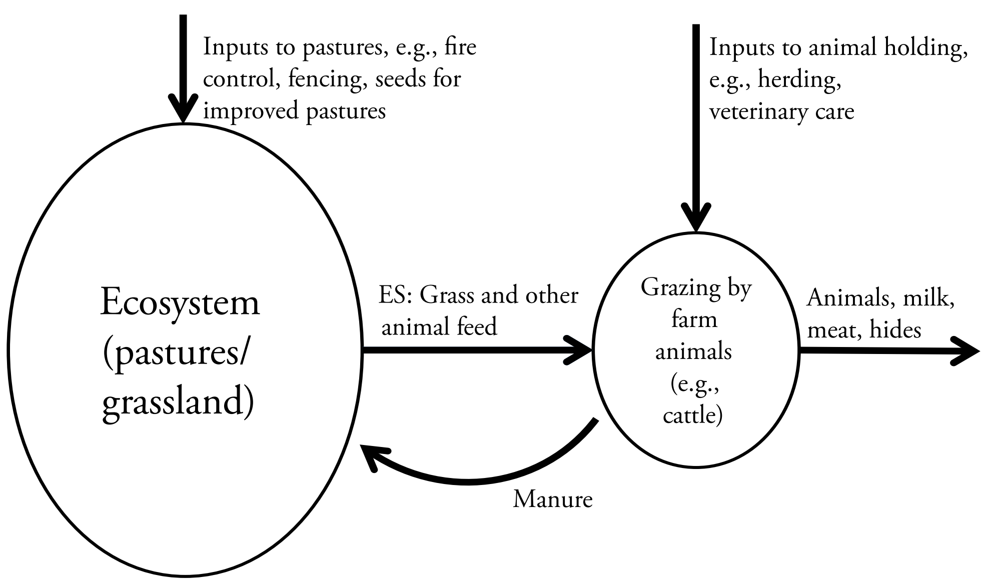


Provisioning of fodder for livestock

A3.3 In livestock grazing, the service supplied by the ecosystem relates to the amount of animal fodder grazed by livestock. This animal fodder includes annual and perennial grasses and herbs, leaves from trees, etc. The livestock holding system may be more or less intensive, for instance, free-ranging cattle grazing on large stretches of semi-arid rangeland, or dairy cattle grazing on confined pastures. The land manager may invest in managing the overall ecosystem, for instance, by sowing improved pasture varieties, or by building fences or firebreaks. Livestock holding is the activity undertaken by the land manager in the ecosystem, involving all aspects related to animal production and resulting in outputs of animals, wool, milk, meat, hides, etc.

A3.4 The ecosystem service can be measured in physical terms based on the amount of fodder grazed on by animals on an annual basis. The quality of fodder will normally vary in terms of palatability, nutrient contents, etc. A part or all of the manure is normally returned to the field, contributing to maintaining soil fertility in the ecosystem (see figure A3.2).

Figure A3.2
Provisioning of fodder for livestock



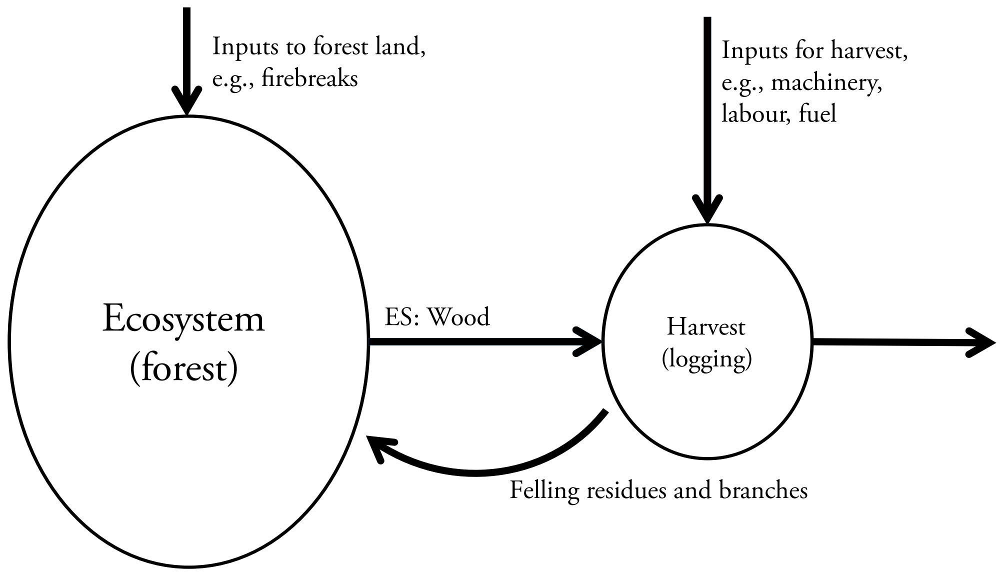
Provisioning of wood and non-timber forest products

A3.5 Wood production includes the production of timber and firewood in natural, semi-natural or plantation forests. Non-timber forest products (NTFPs) include a broad range of products that can be harvested in a forest, such as fibres (e.g., rattan), fruits, mushrooms and pharmaceutical products. Plantation forests are considered cultivated biological resources and are characterized by relatively significant levels of economic activity in the growing process, including the construction of firebreaks, reforestation with specific species, the spraying of pesticides, and the thinning of branches to promote growth.

A3.6 Consistent with the application of the distinction between cultivated and natural biological resources, the flows related to wood from naturally regenerated forests and NTFPs are presented in figure A3.3. The flows related to wood from plantations should be illustrated following the same logic governing figure A3.1 in relation to provisioning services for crop production.

A3.7 For logging, a number of inputs are required, such as labour, saws and trucks. The product resulting from the logging is logged wood, with felling residues returned to the ecosystem. Wood can have a wide range of qualities. Both the benefit (logged wood) and the ecosystem services (wood) can be measured in terms of kilograms per unit area per year. The difference between the two lies in the fact that the ecosystem service represents wood at the moment immediately before it is felled. The benefit arises immediately upon felling.

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



Provisioning of fish and other aquatic and marine species

A3.8 Marine or inland waters (lakes and rivers) supply fish and other species (shrimps, shellfish, seaweed, etc.). There is generally little investment in maintaining the state of the ecosystem, although monitoring or enforcement activities may be undertaken and, on specific occasions, restocking of specific lakes may be carried out. However, inputs are required for the harvesting of fish and other species, involving boats, nets, labour, etc.

A3.9 The ecosystem service is the fish as it is harvested (corresponding to the "gross removal"). The benefit resulting from the activity of fishing is also fish. The ecosystem service may be measured in physical terms as the quantity of fish caught (i.e., the gross removal from the ecosystem), recording differences between species, as appropriate. Discarded catch is usually returned to the ecosystem. Often, the discarded catch consists mainly of dead specimens which do not lead to a restocking of the ecosystem.

A3.10 In the case of aquaculture, the ecosystem services are more akin to those recorded for livestock. Thus, the natural feed and other natural inputs are the ecosystem services that represent the contribution of the ecosystem to the growth of the fish or other aquaculture products. Aquaculture operations that involve no connection to a broader ecosystem (e.g., raising of fish in tanks) would be recorded as having no associated ecosystem services.

Provisioning of water

A3.11 Freshwater can be extracted from deep or shallow aquifers, and from surface water, including lakes, rivers or man-made reservoirs. The supply of water from deep aquifers is not strongly linked to ecosystem functioning, since these reservoirs tend to depend on geologic water resources. The extraction of water from deep aquifers that are not replenished on human timescales should therefore be interpreted as comprising flows of abiotic services.

A3.12 For both surface water and (renewable) water extracted from shallow aquifers, both the quantity and the quality of water generally depend on ecosystem functioning. Water from rivers, lakes or other reservoirs may be purified by ecosystems, in particular if it has passed through a wetland that has the capacity to break down organic pollutants, and absorb inorganic pollutants. Water pumped up from aquifers or other subsurface groundwater sources is often less polluted than surface water because of the capacity of ecosystems to break down or bind pollutants and filter micro-organisms harmful to human health. Often, headwaters or entire watersheds important for drinking water production are protected and managed as drinking-water extraction areas.

A3.13 Water supply therefore combines elements of both a provisioning and a regulating service. It is a provisioning service in the sense that the extraction of water involves a flow from the ecosystem to society; however, underlying the presence of the water are a number of regulating processes such as water storage (inter- or intra-annual) and water purification.

A3.14 The water accounts presented in the SEEA Central Framework and in SEEA-Water detail the methods for accounting for water resources including deep aquifers. In contrast, in SEEA Experimental Ecosystem Accounting, the focus is on ecosystems' capacity to support water extraction. The approach taken is to analyse the provisioning of water as an ecosystem service: the ecosystem service is the amount of water (before treatment) extracted from a surface-water source or a shallow aquifer.

A3.15 Investments may be made in order to protect the ecosystem (generally a watershed) supplying the water (e.g., in adjusted land management, monitoring of water quality, creation of retention basins) and to transform the extracted water into drinking water. The extracted, untreated water enters the production function of the drinking water–company, or of the household consuming the water. The household may either consume this water directly, or filter it before consumption.

Regulating services

Sequestering of carbon and carbon storage

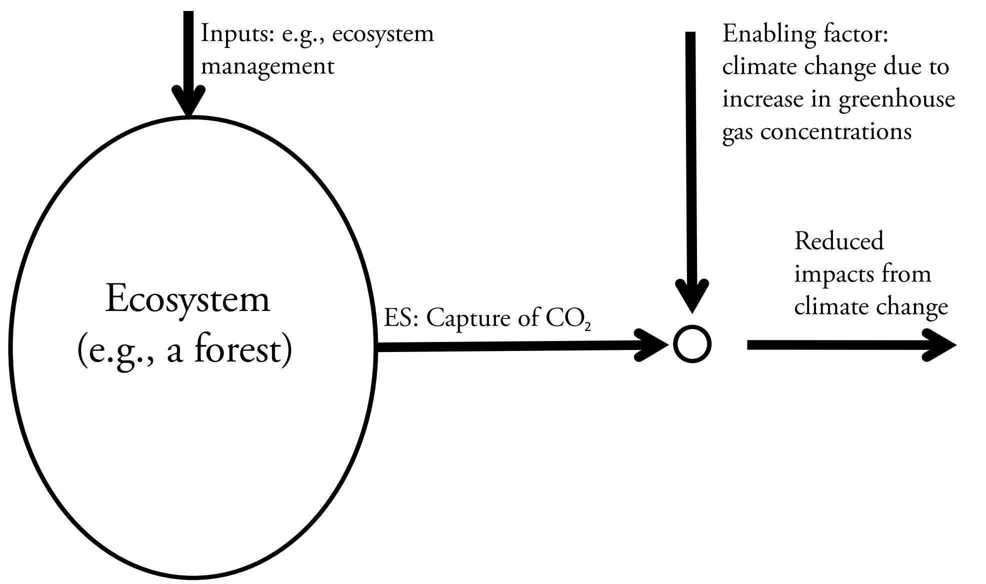
A3.16 Often, the services of sequestering carbon and carbon storage are covered by a single term, "carbon sequestration". However, they represent significantly different ecosystem services, albeit linked within the broader carbon cycle. Both services are important for ecosystem management and therefore for ecosystem accounting. The release of carbon stored in above-ground biomass or in below-ground stocks, such as peatlands, is a significant source of greenhouse gas emissions worldwide. It is also the subject of much debate in the international arena, in particular with regard to the UN-REDD payment mechanism.

A3.17 For the purpose of ecosystem accounting and in order to capture both the stock and the flow aspect, the following conceptualization of this ecosystem service is used. Analogous to other ecosystem services, the sequestering of carbon and carbon storage are service flows that can have only positive values. In both cases, the flows are expressed as tonnes of carbon equivalent per year, and should be specified for spatially defined areas which can be aggregated for the purpose of national-level ecosystem accounting. The service of sequestering carbon is equal to the net accumulation of carbon in an ecosystem due to both growth of the vegetation and accumulation in below-ground carbon reservoirs. The ecosystem service of carbon storage is the avoided flow of carbon resulting from maintaining the stock of above- and below-ground carbon sequestered in the ecosystem.

A3.18 Capturing the second part, that is, the flow that can be attributed to maintaining carbon in storage, entails calculating the avoided emissions. Under this approach, the avoided emissions relate only to the part of the stored carbon that is at clear risk of being released in the short term owing to land-use changes, natural processes (e.g., fire) or other factors. No service flow is recorded if stocks at risk of being released are in fact released, but positive service flows are recorded where stocks at risk remain in storage.

A3.19 The conceptual model of the ecosystem service as a function of ecosystem state and enabling factors is presented in figure A3.4, which shows that ecosystem management will generally affect the net sequestration and/or the storage of carbon in the soil. The enabling factor for this service is the occurrence of climate change, which causes carbon sequestration and storage to provide economic benefits resulting from avoided damages, at present and in the future.

Figure A3.4
Sequestering of carbon



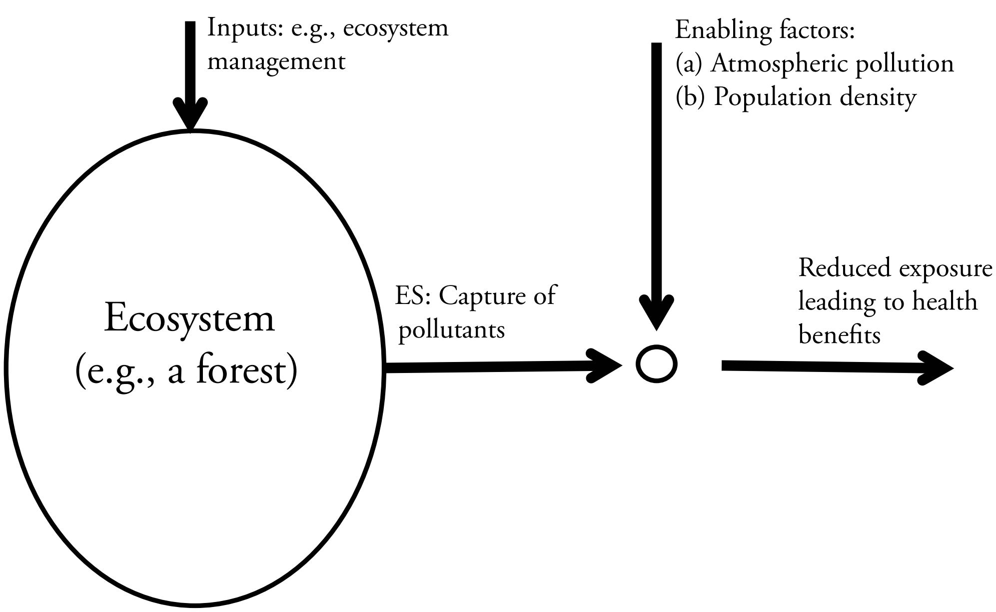
Air filtration

A3.20 Air pollution arising from particulate matter (*PM*) (in particular the smallest fraction of *PM*, namely, *PM*2.5, with a diameter of 2.5 micrometres (μm) or less) is a major health problem in many countries. Statistically significant relationships between *PM* concentration and cardiovascular and respiratory diseases, as well as lost working days due to air pollution–related illnesses, have been demonstrated in a range of studies. Air pollution removal takes place through the interception of *PM* by leaves (dry deposition). The amount of interception depends on the state and management of the ecosystem (for instance, on an annual basis, evergreen trees capture more *PM* than deciduous trees). Two enabling factors are needed to turn the ecosystem process of deposition into an ecosystem service: a certain pollution load (which can be measured in terms of *PM* concentrations); and an exposure of people to air pollution in the zone affected by *PM* deposition by the ecosystem.

A3.21 The total amount of particulate matter deposited in an ecosystem can be estimated as a function of the area, deposition velocity, time period and average ambient PM2.5 concentration, according to the formula $PM{\downarrow}=A\times V_d\times t\times C$, in which $PM{\downarrow}$ = deposition of *PM*2.5 (kg), A = area (m^2), V_d = deposition velocity as a function of the leaf area index of the vegetation (LAI) (mm s^{-1}), t = time (s), and C = ambient $PM2.5$ concentration (kg/m^3). The deposition velocity depends on the vegetation type. There is an increasing number of types of measurements of deposition velocities as a function of vegetation type, in particular in European countries.

A3.22 The distance over which vegetation influences air quality is a subject of uncertainty. The 2012 UK National Ecosystem Assessment assumed that health benefits from air filtration by forests occur only at short distances (<1 km) from the forest. Other studies state that damage assessments of particulate matter pollution need to consider that air pollution (PM) can spread from an emission source over distances of several hundred kilometres, which means that the effect of large forests on air quality may be noticeable at large distances from the forest edge.

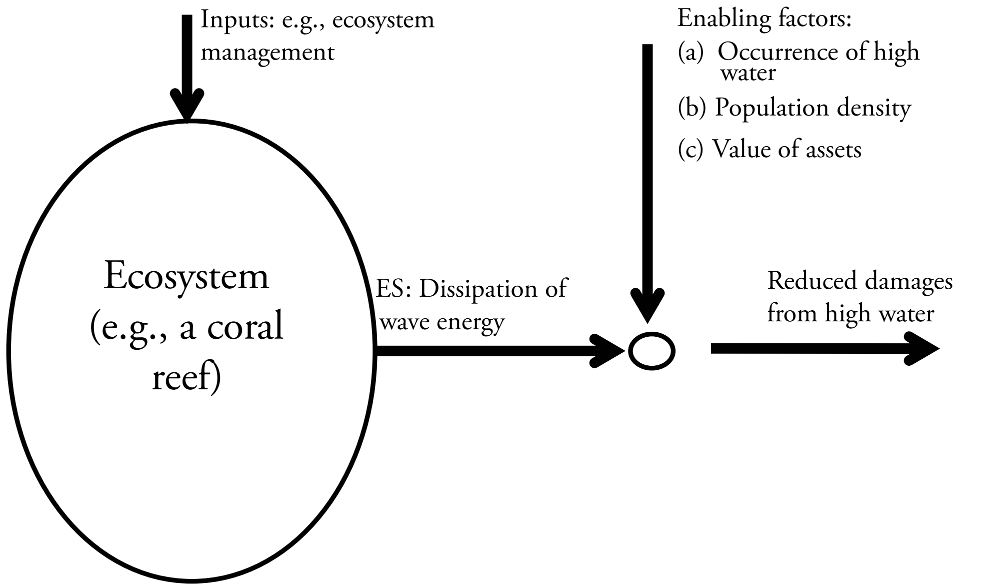
Figure A3.5
Air filtration



Flood protection

A3.23 It is clear from a range of studies that specific ecosystems can reduce the extent and intensity of floods, thus reducing the risk of damage to built environments and other ecosystems. Ecosystems such as mangroves, dunes or coral reefs, and riparian forests, are particularly relevant in this regard. This service is relevant only where there is (a) risk of high water and wave energy as a function of wind patterns and local bathymetrics and (b) the presence of people, economic activity and assets susceptible to loss in the exposed flood risk zone. Storm occurrence and therefore flood risk may be modelled in a probabilistic manner on the basis of the occurrence and magnitude of storms in recent decades and on the basis of climate models accounting for climate change. In coastal areas, the ecosystem service entails the dissipation of wave energy and the prevention of inundation. In inland areas, the ecosystem service entails the channelling and dispersion of water.

Figure A3.6
Flood protection



Cultural services

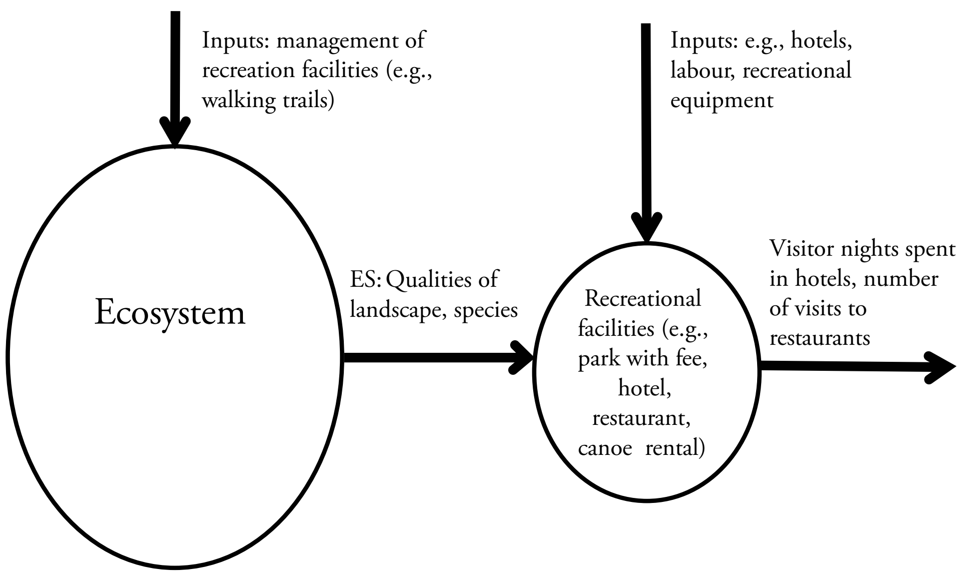
Tourism and recreation

A3.24 Ecosystems provide an opportunity for tourism and recreation. Tourism is generally interpreted as involving overnight stays, potentially of visitors from abroad, and recreation is more usually associated with day trips. The service usually involves some degree of investment in the ecosystem, for instance, to mark out and build walking trails, cycling paths and camping sites. In physical terms, this ecosystem service can be measured on the basis of the number of people visiting the ecosystem.

A3.25 The benefits accrue to the visitors themselves, and to nearby suppliers of tourism and recreational facilities, to the extent that they can attribute their operation to the ecosystem. For instance, some tourism facilities exist only because of the presence of the ecosystem, as in the case of an enterprise renting out skis or canoes. For other enterprises, the picture is mixed, and only part of their activity may be attributable to the ecosystem, as in the case of hotels or restaurants located in or near natural parks.

A3.26 Physical measurement of the ecosystem involves recording the number of visitors to ecosystems, in terms of visitor days or overnight stays. Areas such as national parks that are publicly accessible are most relevant for this service. As in the case of provisioning services, the use of ecosystem services in tourism entails engagement by people in the ecosystem in specific activities—in this case, recreational ones.

Figure A3.7
Tourism and recreation services



Chapter IV

Accounting for ecosystem assets in physical terms

4.1 Introduction

4.1 ***Ecosystem assets are spatial areas containing a combination of biotic and abiotic components and other characteristics that function together.*** Ecosystem assets are measured in terms of *ecosystem condition* and *ecosystem extent*, and in terms of *expected ecosystem services flows*. Generally speaking, the capacity of an ecosystem asset to generate a basket of ecosystem services can be understood as a function of the condition and the extent of that ecosystem.

4.2 There will not be a clear-cut or simple relationship between these two forms of measurement. Instead, the relationship is likely to be non-linear and variable over time. For example, if an ecosystem asset such as a river basin has the capacity to provide a significant amount of water for human consumption, then it may be that increases in population (up to a certain point) will not lead to a change in ecosystem condition but will lead to a rise in ecosystem services. Also, dependencies between ecosystem assets may be such that declines in ecosystem condition in, say, spawning grounds for salmon ultimately induce declines in ecosystem services from fishing in other locations. More generally, a full appreciation of the impact of human activity on ecosystem assets may often not become apparent for considerable periods of time.

4.3 Given this situation, the standard asset accounting models, which assume relatively direct links between streams of economic benefits and the condition of assets, are insufficient. It is therefore important that both the ecosystem service flows and the ecosystem condition and extent be assessed in tandem.

4.4 Fortunately, for the purposes of SEEA Experimental Ecosystem Accounting, it is not necessary to build complete ecosystem models and measure every possible stock and flow. Rather, what is needed is to identify the aspects of ecosystem assets that are most relevant to obtaining aggregated information for measuring trends and comparing ecosystem assets.

4.5 This being the case, the approach outlined here involves (a) a decomposition of ecosystems into relevant characteristics and (b) an assessment of each characteristic in the context of the ecosystem as a whole. From the information set produced, conclusions may be drawn about the overall condition of the ecosystem and its capacity to deliver services based on expected patterns of future ecosystem use. In addition, using information on flows of ecosystem services as described in chapter III, expected ecosystem service flows based on expected patterns of ecosystem use can be estimated. Assessments of ecosystem degradation and ecosystem enhancement can be made using information on changes in ecosystem condition and extent and expected ecosystem service flows.

4.6 The challenge in applying this approach is to identify the appropriate characteristics and then determine the relevant indicators. In particular, it is important not to lose sight of the fact that, as ecosystems function through the working together of all components, the approach does not necessarily reduce to a simple case of adding up the assessments of each characteristic.

4.7 The present chapter outlines ways in which this indirect approach to the assessment of ecosystem assets may be carried out within an accounting structure. In section 4.2, the main concepts used in ecosystem asset accounting are defined. In section 4.3, the steps required to compile information on ecosystem assets are described and the aggregation of various indicators is discussed. The final two sections summarize two specific forms of ecosystem asset accounting: accounting for carbon (sect. 4.4) and accounting for biodiversity (sect. 4.5).

4.2 General approaches to assessing ecosystem assets

4.8 The assessment of ecosystem assets is considered to encompass measurement of three key concepts which were introduced in chapter II: ecosystem condition, ecosystem extent and expected ecosystem service flows. The present section also discusses the relevant concepts as they relate to approaches to measurement. There are strong relationships among all three concepts; but for the purposes of exposition, a distinction is made between the measurement of ecosystem condition and extent on the one hand and expected ecosystem service flows on the other.

4.2.1 Assessing ecosystem condition and extent

4.9 Assessment of ecosystem extent generally focuses on measuring land cover, although the approach will be dependent on the definition of the spatial areas used for accounting. In this regard it is likely that the focus will be on determining areas and changes in areas of various LCEUs (e.g., forests, wetlands). The measurement of ecosystem extent will enable the location of an ecosystem asset on the surface of the Earth and the location in relation to other ecosystem assets to be identified. These two aspects of measurement create the spatial foundations for ecosystem accounting.

4.10 Measures of ecosystem condition are compiled in two stages. In the first stage, a set of relevant key characteristics such as water, soil, vegetation, biodiversity, carbon, nutrient flows are selected and various indicators concerning these characteristics are chosen. In the second stage, the indicators are related to a reference condition.

4.11 The selection of characteristics and indicators should be made on a scientific basis to ensure that there is an overall assessment of the ongoing functioning and integrity of the ecosystem asset. Thus, movements in the indicators should be responsive to changes in the functioning and integrity of the ecosystem as a whole. Generally, there will not be a single indicator for assessing a single characteristic.

4.12 The specific spatial location of an ecosystem asset, particularly its relation to other ecosystem assets, is an important consideration in identifying and measuring inter-ecosystem flows and hence in understanding the condition of an ecosystem asset. Inter-ecosystem spatial features, such as connectivity and landscape configuration, constitute one type of ecosystem characteristic.

4.13 Individual ecosystem characteristics are not considered to be ecosystem assets in their own right. In some cases, involving, for example, water resources and soil resources, it is possible to undertake distinct asset accounting as described in the SEEA Central Framework.

However, this approach is different from the spatial-based accounting for ecosystem assets that is described here.

4.14 Where there is a strong understanding of the various processes operating within an ecosystem, it may be possible to identify specific indicators (e.g., measures relating to a specific critical species) that can represent the overall condition of an ecosystem asset. Such proxy measures may be of particular use in providing indicators of change in ecosystem assets that are suitable for high-level (national or regional) ecosystem accounting purposes.

4.15 As regards the second stage, there are a number of options available for determining a reference condition, each with different conceptual underpinnings. One approach, reflecting a purely accounting perspective, is to measure changes relative to the condition at the beginning of the accounting period. Thus, when accounts are compiled for any given accounting period, the measure of change in condition would refer to the change from the beginning of the period to the end. This reference condition is sufficient for accounting purposes but is limited in providing an assessment of the relative condition of multiple ecosystem assets since, when this approach is used, all ecosystems are assumed to have the same condition relative to their specific characteristics at the beginning of the period.

4.16 An alternative reference condition of particular importance for ecosystem accounting reflects the degree or nature of human influence on an ecosystem. Thus, a reference condition may reflect an ecosystem that is relatively undisturbed or undegraded by humans, or a situation in which the ecosystem is in relative stability. For example, long-standing agricultural areas may be considered ecosystem assets that are relatively stable and not undergoing degradation in terms of their ecosystem characteristics (e.g., soil condition) or their capacity to provide a stable flow of agricultural products.

4.17 The use of these types of reference condition approaches recognizes that ecosystems that are naturally more structurally diverse or more species-rich (e.g., tropical rainforests) are not necessarily considered to have a higher condition than ecosystems that are naturally less structurally diverse or less species-rich (e.g., an Arctic tundra).

4.18 One means of utilizing the concept of a reference condition is to relate all of the relevant indicators to the same point in time (usually by setting the values of the indicators equal to 100 at that time). By using the same point in time for different ecosystem assets, it is possible to make assessments of the relative condition of those assets. Within the context of this approach, one might select a point in time before which significant patterns of recent landscape change due to human activity were not in evidence. Note that selecting more recent periods as reference conditions would effectively entail treating equally ecosystem assets ranging from the relatively natural to the relatively human-influenced.

4.19 Very significantly, while reference condition accounting leads to the recording of ecosystem condition scores between 0 and 100, those scores cannot be used to determine whether the condition of the ecosystem is good or bad. Ecosystem condition may be assessed independently of the use of an ecosystem but, a priori, any given level of condition is not necessarily good or bad.

4.20 Relevant to this subject is the need to distinguish a reference condition from what may be regarded as a target condition, which is determined as a function of economic, environmental and social considerations and reflects an explicit or implicit preference for a particular use of an ecosystem, and the associated flows of particular ecosystem services. Ecosystem accounting does not include the use of target conditions. The use of a reference condition does not therefore imply that all ecosystems should, ideally, have a condition score of 100. A reference condition provides only a comparison point or baseline to which current indicators can be scientifically compared over time.

4.21 Most of the focus in condition accounting is on changes in condition and extent over time rather than on the actual condition score. However, while the actual ecosystem condition may not be a key indicator in some circumstances, known thresholds in ecosystem condition could be such that, where the condition of particular characteristics falls below relevant thresholds, the whole ecosystem would be in danger of collapse. Thus, at high degrees of human influence, the actual condition scores could be of particular relevance. Measures of ecosystem condition may thus allow for consideration of the resilience of ecosystems.

4.22 Measures of changes in ecosystem condition and extent may also provide an indirect measure of intra- and inter-ecosystem flows, since changes or disruptions in these ecosystem flows—for example, due to changes in land use within an ecosystem—will be reflected in measures of ecosystem condition. Measures of ecosystem condition and extent should therefore take into account relationships and dependencies between ecosystem assets.

4.23 There may be some overlap between measures of ecosystem extent and ecosystem condition in the sense that, at certain scales of analysis, changes in extent may also be considered to be encompassed by the measurement of overall changes in ecosystem condition. At the same time, it is not considered that measures of changes in ecosystem extent can be used as a substitute for measuring changes in ecosystem condition.

4.2.2 Assessing expected ecosystem service flows

4.24 The other means of measuring an ecosystem asset entails focusing on assessment of the capacity of the asset to generate an expected combination (or basket) of provisioning, regulating and cultural services. Because the generation of some ecosystem services involves the extraction and harvest of resources, and since ecosystems can undergo regeneration, there will be a need to estimate the extent of the extraction and regeneration that will occur, and the overall sustainability of human activity within the ecosystem.

4.25 Moreover, expected ecosystem services flows are dependent upon assumptions regarding future use patterns. In general, there will be differences between current use patterns (e.g., overfishing within a particular fishery) and alternative use patterns (e.g., fishing at a sustainable yield).

4.26 For accounting purposes, a specific basket of ecosystem services must be considered, usually based on current patterns of use. At the same time, the same framework can be used to organize information for various scenarios and alternative ecosystem uses. In this context, it is also possible to develop scenarios of ecosystem asset use that "optimize" the flow of ecosystem services from a given ecosystem asset. While the development of optimized scenarios is not the main purpose of ecosystem accounting in the SEEA, it is nevertheless an important analytical application.

4.27 There are relationships existing among the condition of an ecosystem asset, its pattern of use and the expected basket of ecosystem services. However, while ecosystem condition may be assessed without considering measures of ecosystem services, the measurement of ecosystem assets in terms of their capacity to generate ecosystem services must involve assessment of ecosystem condition.

4.28 It is not necessarily the case that ecosystems with relatively lower condition will generate fewer ecosystem services. However, there is likely to be a close relationship between reductions in condition on the one hand, and the capacity of an ecosystem to generate ecosystem services sustainably on the other. At the same time, a change in condition may lead to a decrease in the capacity to supply some services, but an increase in its capacity to supply others.

4.29 It is through the lens of ecosystem services that the connection among ecosystem condition and extent, the benefits obtained, and broader measures of economic and human activity may be perceived. Thus, measurement of expected ecosystem service flows is important in terms of the consideration of trade-offs between ecosystem services and, more broadly, between alternative land uses. Owing to the general framework within which ecosystem services are situated (see figure 2.3), this expected flows-related perspective on the measurement of ecosystem assets can be combined with a broader assessment of both the ecosystem services and abiotic services that may be generated from a given area.

4.2.3 Assessing changes in ecosystem assets

4.30 An important accounting objective is the measurement of changes in ecosystem assets, particularly ecosystem degradation and ecosystem enhancement. These are complex concepts since assets may change owing to a variety of factors, both natural and human-induced. Associated with the different perspectives on the measurement of ecosystem assets are a number of considerations.

Ecosystem degradation and ecosystem conversions

4.31 Broadly speaking, ***ecosystem degradation is the decline in an ecosystem asset over an accounting period***. Generally, ecosystem degradation will be reflected in declines in ecosystem condition and/or declines in expected ecosystem service flows. Changes in ecosystem extent are relevant where they are linked to declines in ecosystem condition or expected ecosystem service flows. Since there may not always be a linear relationship between the condition of an ecosystem and the expected flows of ecosystem services, the measurement of degradation should respect the following two conditions:

(a) Ecosystem degradation should cover only declines due to economic and other human activity, thereby excluding those due to natural influences and events (e.g., forest fires and hurricanes);[37]

(b) Declines in expected ecosystem service flow where there is no associated reduction in ecosystem condition should not be considered ecosystem degradation (e.g., ecosystem degradation is not recorded in cases where, ceteris paribus, provisioning services from forests decline because of reduced logging due to decreases in expected output prices, or where declines in cultural services are due to a rise in national park entry fees).

4.32 This approach to conceptualizing ecosystem degradation is particularly relevant in situations where the extent of an ecosystem asset does not change over an accounting period and, more specifically, in the case of ecosystem assets defined by an EAU (whose area will generally remain stable), when the composition of the EAU in terms of areas of different LCEUs does not change. However, where the extent or composition of an ecosystem asset changes significantly or irreversibly (e.g., owing to deforestation carried out to create agricultural land), the consequences for the definition of ecosystem degradation are less clear and will be correlated with the scale and complexity of the analysis being considered. These types of changes are referred to as ecosystem conversions.

4.33 From one perspective, the use of an area of land for an alternative purpose may result in either a decrease or an increase in expected ecosystem service flows from that area. If there is a decrease, then a case can be made for categorizing this decrease as ecosystem degrada-

37 While declines due to natural events are recorded in ecosystem asset accounts, they are not considered a part of ecosystem degradation.

tion. However, since ecosystem conversions have, as their general effect, increases in some ecosystem services and declines in others, the comparison of expected ecosystem service flows will require assessment of two different baskets of ecosystem services. The situation is further complicated by the changes in inter-ecosystem flows that arise, as the adjacent ecosystem assets may no longer receive or provide the same bundle of flows from or to the converted ecosystem asset. Adjacent ecosystem assets may thus also become degraded.

4.34 Another approach in cases of ecosystem conversion is to focus only on changes in ecosystem condition in the specific area within the ecosystem that has been converted, e.g., the part of the forest that has been converted to agricultural land. From this perspective, it may be considered that ecosystem degradation occurs whenever an ecosystem conversion results in a lowering of ecosystem condition relative to a reference condition within the converted area. Then, irrespective of the impact of a conversion on expected ecosystem service flows from the ecosystem asset as a whole, it may be relevant to record ecosystem degradation so as to reflect an overall decline in condition due to human activity.

4.35 A third approach to ecosystem degradation entails recording changes only when the change in the extent and condition of an ecosystem is so significant that it is not possible for the ecosystem to be returned to a condition akin to a previous one; that is, the change is irreversible. This approach is not followed in SEEA Experimental Ecosystem Accounting, as it is not particularly suitable for a model based on assessment of change over successive accounting periods: recording ecosystem degradation only at the time where it is known that the situation is irreversible would prevent ecosystem accounting from realizing one of its goals, which is ongoing, transparent recording of change in ecosystem assets.

4.36 In the SEEA, the concept of ecosystem degradation is treated distinctly from that of the depletion of natural resources. In the SEEA Central Framework, depletion is defined as "the decrease in the 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" (para. 5.76).[38] The distinction between these two concepts lies in the fact that depletion relates to the decline in a specific resource, while ecosystem degradation relates to the decline of a system that encompasses a range of different resources and various processes. In many cases, depletion of resources such as timber resources and fish stocks should correlate strongly with measures of ecosystem degradation for the ecosystem assets from which the resources are extracted. However, because ecosystem degradation covers a broader range of characteristics, the two concepts should not be equated.

4.37 Overall, while there is general recognition that ecosystem degradation reflects a decline in an ecosystem asset, the precise application of this concept may vary, depending on the nature of the change in the ecosystem asset and on the scale of analysis. The suggestion for accounting purposes is to endeavour to record all of the various reasons for changes in ecosystem assets and, where possible, separate changes in ecosystem extent from changes in ecosystem condition. It is to be noted that changes in expected ecosystem service flows are likely to reflect changes in both extent and condition, but differentiating between these effects presents a challenge.

Ecosystem enhancement and other changes in ecosystem assets

4.38 Ecosystem enhancement is the increase and/or improvement in an ecosystem asset that is due to economic and other human activity. Ecosystem enhancement reflects the results of activities undertaken to restore or remediate an ecosystem asset, i.e., activities beyond those

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38 See also sect. 5.4.2 of SEEA Central Framework for a longer discussion on defining depletion, including the links to ecosystem degradation.

that would only maintain ecosystem condition. As is the case for ecosystem degradation, different measurement perspectives may be considered for ecosystem enhancement that focus on changes in expected ecosystem service flows in combination with changes in ecosystem condition and extent. Again, ecosystem enhancement associated with the conversion of ecosystems to alternative uses requires specific consideration.

4.39 Increases and declines in ecosystem assets that are not due to economic or other human activity should be recorded as other changes in ecosystem assets. Changes due to natural regeneration and normal natural loss should incorporate inter-ecosystem flows (both into and out of the ecosystem) and should implicitly reflect the ongoing intra-ecosystem flows, since it is these flows that underpin the regeneration process. For some purposes, it may be useful to account explicitly for certain inter-ecosystem flows so as to highlight dependencies between ecosystem assets (e.g., flows of water between ecosystems). It may be the case that reductions in inter-ecosystem flows reduce the capacity to generate some ecosystem services in dependent ecosystems.

Other considerations in the measurement of changes in ecosystem assets

4.40 A particular feature of ecosystem assets is that they have the potential to regenerate, within the context, of course, of existing thresholds, irreversibilities and varying time horizons. This potential means that they may provide the same ecosystem services over an indefinite length of time. Consequently, over the long term, it is possible for an ecosystem asset to undergo no ecosystem degradation—that is, the expected flow of a given basket of ecosystem services is unending.

4.41 Measurement of the degree of ecosystem regeneration should take into account normal annual variation in the generation of ecosystem services due, for example, to a year's relative wetness or dryness. It is to be noted that from an accounting perspective, even if the intended management of an ecosystem is such that there are expectations of an ongoing flow of a given quantity of ecosystem services (e.g., through the sustainable management of fisheries), it should not be assumed that the actual flow of services will be equal to the expected flow.

4.42 In practice, consistent with the measurement of the depletion of biological resources as defined in the SEEA Central Framework, it is necessary to account for both reductions in expected ecosystem service flows due to human activity (most commonly through the extraction and harvest of biological resources) and the increases in expected ecosystem service flows (not necessarily of the same services) due to natural regeneration of the ecosystem. To the extent that the reductions are greater than the increases, ecosystem degradation should be recorded.

4.43 For a single ecosystem asset, if, over an accounting period, the increases due to natural regeneration are greater than the reductions due to human activity, then ecosystem degradation should be zero and the extra regeneration should be shown as an addition to ecosystem assets.

4.2.4 Links to standard asset accounting

4.44 The starting point for the approach in SEEA Experimental Ecosystem Accounting is the standard asset accounting model used to account for produced assets in the SNA and as applied to the measurement of individual environmental assets in the SEEA Central Framework.

4.45 The standard asset accounting model focuses on a single asset (most commonly a produced asset) and estimates an expected flow of benefits (in terms of capital services) that will accrue to the user or owner of the asset over a given period of time (the asset life). The pattern of expected flows provides the basis for valuing the asset, determining flows of income and depreciation and assessing how the asset contributes to production.

4.46 While the standard model provides a solid starting point for ecosystem asset accounting, there are some fundamental differences among ecosystem assets which require the introduction of extensions to the standard model. There are four key distinctions between ecosystem assets and produced assets.

4.47 First, ecosystem assets have the potential to regenerate without human involvement. Produced assets must be created (produced) each time as new.

4.48 Second, a single ecosystem asset may generate varying baskets of ecosystem services over a series of accounting periods. In contrast, even if a single produced asset may be regarded as generating multiple capital services, it is assumed that the asset generates the same set of capital services over its life, even if the user of the asset changes and the asset is used in different industries. Thus, a computer continues to provide computer services to whoever uses the computer.

4.49 Third, the ecosystem services from an ecosystem asset may be used by a range of different users (enterprises, households, etc.). In contrast, the capital services from a produced asset are used only by the economic owner of the asset. Typically, the capital services are recorded as an input into a production function internal to an enterprise which ultimately leads to the creation of products. While the products may be consumed by multiple users, the capital services are consumed only by the enterprise itself.

4.50 Fourth, there is not a one-to-one relationship between the capacity of an ecosystem asset to generate ecosystem services and the actual use of ecosystem services in economic and other human activity. In the case of produced assets, their capacity to generate capital services is either fully used or it is assumed that use relative to capacity exists at a relatively stable level. Situations where there are permanently underused produced assets are assumed to be uncommon over a business cycle, whereas for ecosystem assets such situations can easily arise.

4.51 The existence of these four distinctions requires the standard asset accounting model to be adapted for the purposes of accounting for ecosystem assets. These adaptations require reconsideration of some of the often implicit assumptions made in standard asset accounting that should not be transferred automatically to an ecosystem asset accounting context.

4.3 Compiling ecosystem asset accounts

4.3.1 Introduction

4.52 Ecosystem asset accounts are intended to organize non-monetary information regarding the extent and condition of ecosystems, and expected ecosystem service flows. The number of related concepts requires that a large amount of information be integrated and the suggestions made in the present section for accounting tables are intended to serve as a starting point for experimentation in the area of compilation rather than as definitive methodological guidance. All of the ecosystem asset tables provided are designed to give a sense of the broad potential of ecosystem accounting to organize information across a range of areas and from multiple perspectives. It may be useful to keep in mind that these tables summarize information derived from a broader database containing more detailed data on ecosystem condition, changes in condition and extent, and expected ecosystem service flows.

4.53 An important point is that these tables do not contain rows or columns related to aggregate measures of ecosystem assets. Defining ecosystem asset aggregates is problematic owing to the need to define relationships between the various characteristics, an issue discussed in section 4.3.3. It is recommended, as a matter of practice in compilation, that the focus first be placed on the description and measurement of the relevant characteristics before aggregation is considered.

4.54 Of the statistical units in the model outlined in chapter II, the ecosystem accounting unit (EAU) is the most applicable to the measurement of ecosystem assets, since it should be relatively stable in area over time. However, the most logical choice with respect to the organization and measurement of relevant information may be the LCEU, since the types of characteristics of interest and types of ecosystem services flow are likely to vary most significantly by type of LCEU.

4.3.2 Accounting tables for ecosystem assets

4.55 When compiling ecosystem asset accounts at a national level, that is, across multiple EAUs and various types of LCEUs, it is likely to be most useful to develop a common set of data and indicators for particular ecosystem characteristics in different types of LCEU. Further, it is likely to become apparent that there are some characteristics of ecosystems, notably soil, biomass and water, that are common to and essential in all terrestrial ecosystems.

4.56 Given the spatial diversity and heterogeneity of ecosystems, ecosystem asset accounts will generally need to be developed in a geographic information system (GIS) context. Although the specific data sets will need to be determined on a country basis, there are a number of basic resource accounts that are fundamental to ecosystem accounting and will typically need to be developed in each country. These include, among others: (a) land accounts; (b) carbon accounts; (c) water accounts; (d) soil and nutrient accounts; (e) forest accounts; and (f) biodiversity accounts. A number of these accounts are described in the SEEA Central Framework.

Accounts for assessing ecosystem extent

4.57 A useful first step in the process of assessing ecosystem assets is the organization of information concerning ecosystem extent. Of particular interest in this regard are land-cover accounts as described in the SEEA Central Framework. As an indication of the type of accounting that is possible, table 4.1 sets out the physical account for land cover as presented in table 5.13 of the SEEA Central Framework. It shows the opening and closing stock of land in hectares for a variety of classes of land cover and contains various entries for additions and reductions in the area of each land-cover type. For ecosystem accounting purposes, the definition of the categories of land cover should align with the definition of types of LCEU which, as discussed in chapter II, may take into account other factors than just land cover. Nonetheless, the general guidance offered in the SEEA Central Framework provides a starting point for compilers in this area.

Table 4.1
Physical account for land cover (*hectares*)

	Artificial surfaces	Crops	Grassland	Tree-covered area	Mangroves	Shrub-covered area	Regularly flooded areas	Sparse natural vegetated areas	Terrestrial barren land	Permanent snow, glaciers and inland water bodies	Coastal water and inter-tidal areas
Opening stock of resources	12 292.5	445 431.0	106 180.5	338 514.0	214.5	66 475.5	73.5	1 966.5		12 949.5	19 351.5
Additions to stock											
Managed expansion	183.0	9 357.0									
Natural expansion			64.5								1.5
Upward reappraisals			4.5								
Total additions to stock	183.0	9 357.0	69.0								1.5
Reductions in stock											
Managed regression		147.0	4 704.0	3 118.5	9.0	1 560.0	1.5				
Natural regression					1.5	64.5					
Downward reappraisals						4.5					
Total reductions in stock		147.0	4 704.0	3 118.5	10.5	1 629.0	1.5				
Closing stock of resources	12 475.5	454 641.0	101 545.5	335 395.5	204.0	64 846.5	72.0	1 966.5		12 949.5	19 353.0

Source: SEEA Central Framework, table 5.13.
Note: Crops include herbaceous crops, woody crops and multiple or layered crops.

4.58 Many countries have a variety of land-cover and related statistics and this information is becoming more developed as remote-sensing technology is increasingly applied in these contexts. It is recognized that ongoing international collaboration on the development of land accounts for the purposes of ecosystem accounting will be an important part of the development and implementation of the SEEA.

4.59 A potential area of extension is that of the compilation of land-cover change accounts, which reconcile estimates of the area of land-cover types between the beginning and end of an accounting period. The change between land-cover types can be organized to highlight particular sources of change and ecosystem conversion such as deforestation, urban expansion. Such accounts may be of significant use in the derivation of measures of ecosystem degradation where the cause of the ecosystem change is of particular relevance. A land-cover change account builds on the information contained in a land-cover change matrix (as shown in table 5.14 of SEEA Central Framework), which indicates only the changes in land cover over time rather than recording the human and natural causes of the change.

Accounts for assessing ecosystem condition

4.60 Depending on the characteristics of interest, assessment of ecosystem condition may benefit substantially from the development of basic resource accounts for individual ecosystem characteristics that are susceptible of direct quantitative measurement. Basic resource accounts contain information on opening and closing stocks and changes in stocks for specific characteristics such as water resources, timber resources, carbon and biodiversity.

4.61 The accounting structure for basic resource accounts should be based on the asset accounts presented in chapter V of the SEEA Central Framework. The SEEA Central Framework describes specific asset accounts for water resources, timber resources and a range of other individual environmental assets. Section 4.4 and 4.5 in this chapter present basic resource accounts for carbon and biodiversity (the latter focusing on accounting for species).

4.62 Table 4.2 presents the physical asset account for water resources as described in the SEEA Central Framework (and contained in table 5.25 thereof). It is structured to show opening and closing stocks of water resources and the additions and reductions in water resources over an accounting period. As noted, similarly structured accounts can be compiled for other resource types. For ecosystem accounting purposes, an important extension of the asset account structure would encompass recording of inter-ecosystem flows. Those entries would require the development of resource accounts that are spatially specific, that is, incorporating data for a particular EAU or LCEU.

Table 4.2
Physical asset account for water resources (*cubic metres*)

	Type of water resource						
	Surface water				Groundwater	Soil water	
	Artificial reservoirs	Lakes	Rivers and streams	Glaciers, snow and ice			Total
Opening stock of water resources	1 500	2 700	5 000		100 000	500	109 700
Additions to stock							
Returns	300		53		315		669
Precipitation	124	246	50			23 015	23 435
Inflows from other territories			17 650				17 650
Inflows from other inland water resources	1 054	339	2 487		437	0	4 317
Discoveries of water in aquifers							
Total additions to stock	1 478	585	20 240		752	23 015	46 071
Reductions in stock							
Abstraction	280	20	141		476	50	967
for hydropower generation							
for cooling water							
Evaporation and actual evapotranspiration	80	215	54			21 125	21 474
Outflows to other territores			9 430				9 430
Outflows to the sea			10 000				10 000
Outflows to other inland water resources	1 000	100	1 343		87	1 787	4 317
Total reductions in stock	1 360	335	20 968		563	22 962	46 188
Closing stock of water resources	1 618	2 950	4 272		100 189	553	109 583

Source: SEEA Central Framework, table 5.25.
Note: Dark grey cells are null by definition.

4.63 Basic resource accounts do not provide a direct assessment of ecosystem condition. Rather, following an accounting approach, they organize information that is directly relevant to the assessment of certain ecosystem characteristics and, as shown below, these data can be combined to provide a basis for an overall assessment of an ecosystem asset.

4.64 While tracking stocks and flows of carbon and water across different spatial areas does not provide a direct assessment, it can provide significant insights into changes in ecosystem assets, particularly a broad assessment of change. This reflects the significance of carbon and water within ecosystem processes. Thus, the compilation of basic resource accounts, in the context of the general framework described here, may serve as a useful starting point for compilers. The choice of such a starting point is also supported by the generally good availability of data and the presence of guidelines and standards for the compilation of relevant statistics and accounts (see, e.g., SEEA-Water (United Nations, 2012)).

4.65 Using data in part from basic resource accounts, table 4.3 presents a broad structure for organizing information on ecosystem extent and condition for a given ecosystem asset.

In this case, the ecosystem asset is an EAU assessed at a particular point in time—the end of the accounting period. Starting at the level of an EAU, it is relevant to assess separately the different types of LCEUs. The characteristics that are shown are purely illustrative and will apply to the assessment of condition in different types of LCEUs to varying degrees. It is recognized, for example, that there may be overlaps between the characteristics of vegetation and biodiversity; but in a systems context, such overlaps are inevitable and there must be detailed consideration of the relevant biophysical relationships in the selection of characteristics.

4.66 For each characteristic, there are likely to be a number of relevant indicators; for water, for example, they may relate to pollutant content, number and diversity of fish species and the variability of river flows. Some indicators, for example, river flows, may emerge from the basic resource accounts described above.

4.67 In certain cases, it may be possible to use some indicators to cover a range of characteristics. Of particular interest in this regard is the measurement of stocks and flows of carbon contained in biomass and soil which may be a broad and powerful indicator for use in assessing changes in ecosystem condition. Basic resource accounts for carbon follow the structure of asset accounts of the SEEA Central Framework. Section 4.4 describes the key features of accounting for carbon.

Table 4.3
Measures of ecosystem condition and extent at end of accounting period for an EAU

	Ecosystem extent	Characteristics of ecosystem condition				
		Vegetation	Biodiversity	Soil	Water	Carbon
		Examples of indicators				
Type of LCEU	Area	Leaf area index, biomass, mean annual increment	Species richness, relative abundance	Soil organic matter content, soil carbon, groundwater table	River flow, water quality, fish species	Net carbon balance, primary productivity
Forest tree cover						
Agricultural land[a]						
Urban and associated developed areas						
Open wetlands						

[a] Medium to large fields of rain-fed herbaceous cropland.

4.68 The selection of characteristics and associated indicators for the measurement of ecosystem condition should be based on scientifically valid measures. Consequently, to ensure the robustness of the information, it is important that the selection of characteristics and indicators be subject to a scientific accreditation process that can set appropriate measurement standards to ensure the integrity of the accounting system.[39] There is a range of considerations relevant to the establishment of scientific accreditation processes and the selection of characteristics and indicators, which were introduced in section 2.5.5 above.

39 When accounting is conducted in monetary terms, the standard unit of measure is the currency of the country. The use of this measurement unit ensures a consistency and coherence throughout the reporting across different variables (sales, profits, wages, etc.). The fact that such standard units do not exist across the various physical measures accounts for the requirement that there be an accreditation of measurement.

4.69 Each of the indicators included in a table such as table 4.3 are likely to be recorded in different measurement units. Consequently, the compilation of aggregates is not possible without the use of a common measurement unit or weighting procedure. Issues related to aggregation are considered in section 4.3.3.

Accounting for changes in ecosystem condition

4.70 Within the framework of table 4.3, which presents indicators of ecosystem condition at one point in time, it may be instructive to compile accounts that set out the changes in ecosystem condition over an accounting period. Following the broad structure of the asset accounts presented in the SEEA Central Framework, table 4.4 shows a possible asset account for ecosystem condition for a single LCEU. It is assumed that there are no changes in extent. As in table 4.3, the indicators used are likely to be measured in different units.

4.71 Estimating the magnitude of the factors responsible for the various improvements and reductions in condition may be difficult. Consequently, it may be useful to focus solely on net changes in condition over an accounting period, while possibly making distinctions between relatively small, medium and large net changes. This information, for individual indicators, may be most effectively presented in maps where the relative size of the changes is expressed through colour-coding.

Table 4.4
Changes in ecosystem condition for an LCEU

	Characteristics of ecosystem condition				
	Vegetation	Biodiversity	Soil	Water	Carbon
	Examples of indicators				
	Leaf area index, biomass, mean annual increment	Species richness, relative abundance	Soil organic matter content, soil carbon, groundwater table	River flow, water quality, fish species	Net carbon balance, primary productivity
Opening condition					
Improvements in condition					
Improvements due to natural regeneration (net of normal natural losses)					
Improvements due to human activity					
Reductions in condition					
Reductions due to extraction and harvest of resources					
Reductions due to ongoing human activity					
Catastrophic losses due to human activity					
Catastrophic losses due to natural events					
Closing condition					

Accounting tables for expected ecosystem service flows

4.72 The final topic to be considered in the present section is the measurement of expected ecosystem service flows. In table 4.5, estimates of expected ecosystem service flows at a point in time for a single EAU are recorded. The measurement units are discussed below. No aggregation is assumed and additional rows are required for each ecosystem service under consideration.

4.73 Compilation of entries in terms of expected flows of ecosystem services per year rather than in terms of absolute quantities is likely to be most useful, since determining the expected asset life of an ecosystem may not be practical.

4.74 In estimating expected flows, some allowance should be made for normal year-to-year variation in flows of ecosystem services due, for example, to variations in terms of annual dryness or wetness. The range of factors taken into account in the determination of what is "normal" will vary from ecosystem to ecosystem and over time.

4.75 The estimates in table 4.5 rely on measures of ecosystem services and the associated determination of expected flows. Estimates of expected flows in turn require an understanding of the current mix of ecosystem services and of the impacts of changes in condition and extent on future capacity to provide those ecosystem services, within the context of the expected patterns of use and current ecosystem structure. Section 2.4.2 contains some general comments on this issue.

Table 4.5
Expected ecosystem service flows at end of accounting period for an EAU

	Expected ecosystem service flows per year				
Type of ecosystem services	Forest tree cover	Agricultural land[a]	Urban and associated developed areas	Open wetlands	…
Provisioning services					
Regulating services					
Cultural services					

a Medium to large fields of rain-fed herbaceous cropland.

4.76 In addition to these general comments, the following more specific comments on particular ecosystem services are relevant. It is noted that the types of indicators required to convey the capacity of the ecosystem to generate ecosystem services as a function of ecosystem condition and extent may differ significantly for provisioning, regulating and cultural services.

4.77 For provisioning services, indicators need to reflect both the available stock of the service in question that can be harvested, for instance, the standing stock of timber in an ecosystem, and the regeneration or growth rate for these stocks (for instance, the mean annual increment of timber). The regeneration or growth rate is, in turn, dependent on the overall condition of the ecosystem. For instance, forests that are affected by soil degradation are likely to have a lower regeneration rate.

4.78 However, establishing a specific link between regeneration and overall ecosystem condition is not a straightforward exercise, and a range of different variables and complex ecosystem processes are generally involved in the process. Since these factors vary with ecological and climatic conditions, 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. Such assessments will normally require the involvement of multidisciplinary expertise, for instance, specific knowledge of forestry and forest ecology when it is the capacity of an ecosystem to supply timber over time that is being determined.

4.79 Regulating services are related to ecosystem processes, and there is no harvest or extraction involved. Often, regulating services can be linked to specific ecosystem characteristics, although the sustained supply of services (as in the case of provisioning services) depends on the functioning of the ecosystem as a whole. For instance, air filtration involves the capture of air pollutants by vegetation, and the capacity of the ecosystem to trap air pollutants may be related to its leaf area index, that is, the total surface area of leaves, expressed in square metres per hectare (other factors may also be relevant depending on the characteristics of the ecosystem asset). The leaf area index is influenced by degradation or rehabilitation of the ecosystem (e.g., changes in species composition, or in crown cover) but not necessarily related to the condition of the vegetation.

4.80 Typically, the relationship between ecosystem assets and ecosystem services for regulating services has a spatial aspect. For instance, the ecosystem service air filtration occurs only when there are people living in the area where air quality is improved. Likewise, the service flood protection (e.g., by a coral reef or mangrove forest) occurs only if there are people living nearby or there is infrastructure in the zone at risk from flooding. An exception in this case is carbon sequestration, since the impact of one unit of carbon sequestered on the global climate is the same wherever the sequestration takes place.

4.81 Regulating services will generally have a high spatial variability. For instance, both marine flood risk and the mitigation of flood risk by a protective ecosystem vary as a function of local topography and distance from the sea. The spatial aspect of regulating services indicates that their generation is best measured in a GIS context. In a GIS, the processes and/or components of the ecosystem that support the supply of regulating services are recorded, as well as the relevant features of the physical or socioeconomic environment in which the service is generated. The required resolution depends on the specific ecosystem service.

4.82 Changes in the condition and extent of the ecosystem may or may not lead to changes in the capacity to supply regulating services. This depends on which specific ecosystem components or processes are affected. For instance, extinction of a rare endemic species in a forest might affect cultural services but, unless this species was important for ecosystem functioning (e.g., unless its members were non-substitutable pollinators of specific tree species), it is less likely that the air filtration service or the flood protection service provided would be affected.

4.83 Cultural services are highly varied in terms of the type of services generated and the link between the services and the ecosystem assets. Recreational services are related to the attractiveness of an area, which is a function of, for instance, landscape, vegetation, wildlife, visitor facilities, and presence of walking trails. The actual number of people that visit an area is a function of both its attractiveness and the demand for recreation (which, in turn, is related to, for example, population density, income levels and proximity of the ecosystem and, perhaps, to the availability of alternative tourism destinations). Degradation, or investments in restoration of an ecosystem, (reforestation, construction of walking trails, etc.) are reflected in the attractiveness of that ecosystem, but not necessarily in the level of actual service provided (e.g., the actual number of visitors).

4.3.3 Aggregation in ecosystem asset accounting

4.84 The focus in the aggregation of indicators in the context of ecosystem asset accounting is aggregate measures of ecosystem condition and expected ecosystem service flows. As measures of ecosystem extent are all described in a common unit of area, generally hectares, the aggregation of extent measures is not a complex process.

4.85 Approaches to the aggregation of expected ecosystem service flows for asset accounting are similar to approaches to the aggregation of ecosystem service flows over a single accounting period, as discussed in chapter III. The primary difference is that different weighting patterns among ecosystem services may be relevant to account for the changing relative importance of ecosystem services over time. Choosing the relative importance of services that may be incorporated into the estimates of expected service flows is not relevant in the case of a single accounting period. This difference applies even where the expected ecosystem services flow is measured as a rate per year.

4.86 The approaches to the aggregation of ecosystem condition are somewhat different. Depending on the number of indicators, it may be possible to apply a technique suggested for ecosystem services involving the conversion of the indicators to a common "currency", for example, hectares or units of carbon. As the number of indicators increases, this approach may become less tractable.

4.87 Another approach entails relating all the indicators of ecosystem condition for a given reference condition to a particular point in time. This harks back to the second stage in the measurement of ecosystem condition, as described in section 4.2.1 above. While it is possible to use the beginning of the accounting period as a reference condition, for the majority of ecosystem assets, scientific practice commonly applies a pre-industrial benchmark to set the reference condition. Relevant examples include the measures of water quality in the European Union Water Framework Directive[40] and measures of threatened species in the assessment of species biodiversity.

4.88 Following selection of the reference condition, estimates are needed for each indicator for each characteristic at the reference condition. When necessary, the values of the indicators based on the reference condition may be determined through use of reference sites or models of biophysical condition. All observations in the reference period then are set equal to 100 and a current-period condition score may be determined based on changes in the indicators. The determination of a current-period condition score assumes that there is an understanding of the relative importance of movements in each indicator to the overall condition. In particular, it is assumed that the reference condition describes an ecosystem in a balanced state and that all negative deviations (reflected in relative movements in relevant indicators) are of equal importance or are weighted to have equal importance.

4.89 In theory, provided the selection of characteristics and indicators is scientifically robust and the same reference condition is used for all indicators, an overall assessment of ecosystem condition can be made by considering the actual condition scores for the various indicators. While there is a clear logic operating behind the use of the reference-condition approach to aggregation within and across ecosystems, the approach requires testing, as it is generally applied to multiple indicators relating to an individual characteristic (e.g., biodiversity) rather than across multiple characteristics.

4.90 Overall, some aggregation possibilities are available that are conceptually appropriate and aligned with the general accounting framework. However, further research and development are required in this area of ecosystem accounting. Aggregation for ecosystem accounting in monetary terms is discussed in chapters V and VI.

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40 Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

4.4 Accounting for carbon

4.4.1 Introduction

4.91 In the context of accounting for the condition of ecosystem assets, carbon was identified as an important characteristic for which a basic resource account could be compiled (see sect. 4.3). Such an account would provide partial indicators of ecosystem condition such as net carbon balance and primary productivity. Carbon accounts can also provide information to support measures of the ecosystem services of carbon sequestration and storage of carbon. The present section discusses the possible structure of a basic resource account for carbon.

4.92 Given carbon's central place in ecosystem and other environmental processes and its importance to economic and other human activity, accounting for carbon may also assist in providing information for input into a wide range of analytical and policy contexts. For example, carbon stock accounts can complement the existing flow inventories developed under the United Nations Framework Convention on Climate Change[41] and the Kyoto Protocol thereto.[42] The carbon stock accounts presented here also align with the accounting approach of the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD).

4.93 Further, carbon stock accounts can provide consistent and comparable information for policies aimed at, for example, protecting and restoring natural ecosystems, that is, maintaining carbon stocks in the biosphere. Combined with measures of carbon carrying capacity[43] and land-use history, biosphere carbon stock accounts can be used to:

- Investigate the depletion of carbon stocks due to conversion of natural ecosystems to other land uses
- Prioritize use of land for restoration of biological carbon stocks through reforestation, afforestation, revegetation, restoration and improved land management, taking account of differing trade-offs in respect of food, fibre and wood production
- Identify land uses that result in temporary carbon removal and storage

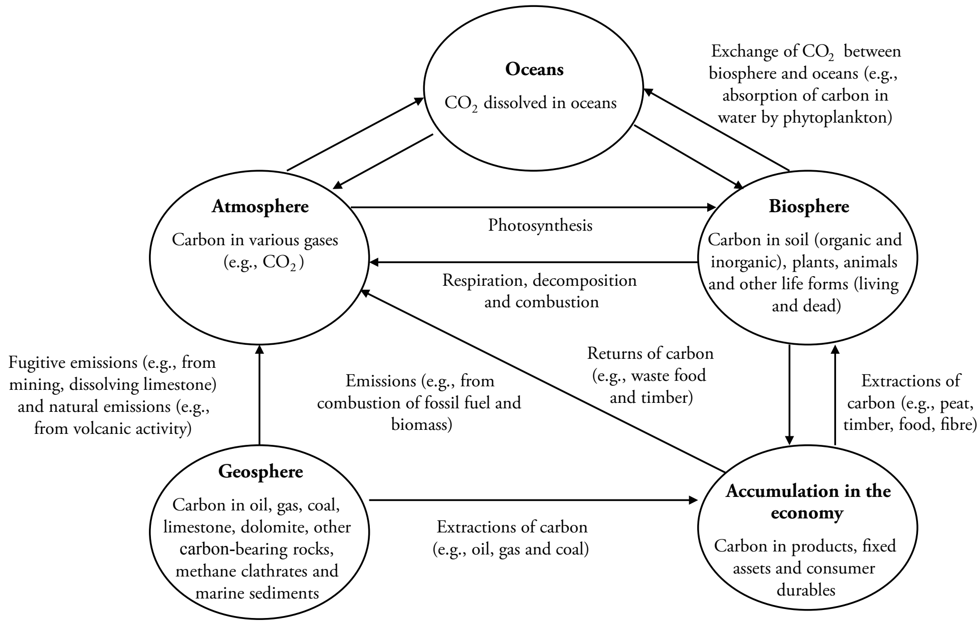
4.94 The fact that carbon plays an extensive role in the environment and the economy calls for a comprehensive approach to its measurement. Accounting for carbon must therefore consider stocks and changes in stocks of carbon of the geosphere, the biosphere, the atmosphere, oceans and the economy. Figure 4.1 presents the main components of the carbon cycle. It is these stocks and flows that provide the context for carbon accounting. Of particular relevance are the qualitative differences between the different stores of carbon. Carbon accounting, and ecosystem accounting more generally, must take these differences into account.

41 United Nations, *Treaty Series,* vol. 1771, No. 30822.

42 Ibid., vol. 2303, No. 30822.

43 The mass of biocarbon capable of being stored in the ecosystem under prevailing environmental conditions and disturbance regimes, but excluding human disturbances (Gupta and Rao, 1994).

Figure 4.1
The main components of the carbon cycle



4.4.2 Carbon stock account

4.95 Applying the accounting principles of completeness and consistency and the approach of the SEEA Central Framework to accounting for residual flows, carbon stock accounts record the stock changes resulting from human activities at any point along the chain: ranging from the changes occurring at their origin in the geosphere and biosphere to changes in the various anthropogenic stocks (e.g., inventories of oil in storage; concrete in fixed assets; wood and plastic in consumer durables; solid waste, i.e., residuals that remain in the economy in controlled landfill sites; and imports and exports) and as residuals to the environment, including emissions to the atmosphere. Carbon stock accounts can assist in informing of the implications of policy interventions at any point along the carbon cycle.

4.96 The structure of a carbon stock account is presented in table 4.6. It provides a complete and ecologically grounded articulation of carbon accounting based on the carbon cycle and, in particular, the differences in the nature of particular carbon reservoirs. Opening and closing stocks of carbon are recorded, with the various changes between the beginning and end of the accounting period recorded as either additions to, or reductions in, the stock.

4.97 Carbon stocks are disaggregated into: geocarbon (carbon stored in the geosphere) and biocarbon (carbon stored in the biosphere, in living and dead biomass and in soils). Geocarbon is further disaggregated into: oil, gas and coal resources (fossil fuels); rocks (primarily limestone); and minerals (e.g., carbonate rocks used in cement production, methane clathrates and marine sediments). Biocarbon is classified by type of ecosystem. At the highest level, ecosystems are terrestrial, aquatic or marine.

4.98 The reservoirs of carbon in the geosphere and biosphere differ in important ways, namely, in the amount and stability of their carbon stocks, their capacity to be restored and the time required for restoration. Different reservoirs therefore have different degrees of effect on atmospheric CO_2 levels (Prentice, 2007). Carbon stocks in the geosphere are generally

Table 4.6
Carbon stock account

Gigagrams Carbon (GgC)	Geocarbon					Biocarbon			Atmosphere	Water in oceans	Accumulation in economy				Total
	Limestone	Oil	Gas	Coal	Other	Terrestrial ecosystems	Aquatic ecosystems	Marine ecosystems			Inventories[a]	Fixed assets	Consumer durables	Waste	
Opening stock of carbon															
Additions to stock															
Natural expansion															
Managed expansion															
Discoveries															
Upward reappraisals															
Reclassifications															
Total additions to stock															
Reductions in stock															
Natural contraction															
Managed contraction															
Downward reappraisals															
Reclassifications															
Total reductions in stock															
Imports and exports															
Imports															
Exports															
Closing stock of carbon															

a Excluding inventories included in biocarbon (e.g., plantation forests, orchards, livestock, etc.).

Note: Dark grey cells are null by definition.

stable in the absence of human activity; however, stock declines as a result of anthropogenic fossil fuel emissions are effectively irreversible.

4.99 The stability of the carbon stocks in the biosphere depends significantly on ecosystem characteristics. In natural ecosystems, biodiversity underpins the stability of carbon stocks by bestowing resilience and the capacity to adapt and self-regenerate (Secretariat of the Convention on Biological Diversity, 2009). Stability confers longevity and hence the capacity for natural ecosystems to accumulate large amounts of carbon over centuries to millenniums, for example, in the woody stems of old trees and in soil. Semi-modified and highly modified ecosystems are generally less resilient and less stable (Thompson and others, 2009). These ecosystems therefore accumulate smaller carbon stocks, particularly if the land is used for agriculture where the plants are harvested or grazed regularly.

4.100 Structuring the carbon stock accounts to capture these qualitative differences between reservoirs is important because reservoirs with different qualities play different roles in the global carbon cycle. For given rates of fossil fuel emissions, it is the total amount of carbon and the time during which that carbon is stored in the biosphere that influence the stock of carbon in the atmosphere.

4.101 A key requirement of carbon accounting is the ability to understand the degree of human influence over a particular ecosystem. In this regard, it may be desirable to distinguish the varying degrees of human modification of ecosystems and, potentially, to introduce these distinctions into a classification. A framework for defining the varying degrees of human modification may be structured to encompass, for example, natural ecosystems, semi-natural ecosystems and agricultural ecosystems. How these types of ecosystems may be distinguished is described in annex A4.

4.102 The row entries in the account follow the basic form of the asset account in the SEEA Central Framework: opening stock, additions, reductions and closing stock. Additions to and reductions in stock have been split between managed and natural expansion and contraction. Additional rows for imports and exports have been included, thus making the table a stock account, as distinct from an asset account. Details on the types of additions and reductions described in the carbon stock accounts are included in annex A4.1.

4.103 Various indicators can be derived directly from carbon stock accounts or in combination with other information, such as land cover, land use, population, and industry value added. The suite of indicators can provide a rich information source for policymakers, researchers and the public. For example, comparing the actual carbon stock of different ecosystems with their carbon-carrying capacities can inform land-use decision-making in cases where there are significant competing uses of land for food and fibre.

4.104 Net carbon balance is one indicator that can be derived from the carbon stock. This indicator signals the change in the stock of carbon in selected reservoirs over an accounting period. Commonly, the focus of net carbon balance measures is on biocarbon but, depending on the analysis, the scope of the measure may also include parts of geocarbon, carbon in the economy and carbon in other reservoirs.

4.5 Accounting for biodiversity

4.5.1 Introduction

4.105 Biodiversity was defined and examined within the context of ecosystem accounting in section 2.1. In section 4.3, it was explained that a basic resource account for biodiversity focusing on the measurement of changes in species could provide information suitable for assessing ecosystem condition. The present section describes a possible structure for such an account.

4.106 At both national and subnational scales, linking biodiversity accounts with the land-cover, land-use and environmental protection expenditure accounts of the SEEA Central Framework can support analysis of the cost-effectiveness of expenditures on habitat and species conservation and the assessment of returns on investment.

4.107 Using the links to economic accounting in the SEEA, it may also be possible to link key drivers of and pressures contributing to biodiversity loss, for example, in terms of measures of energy use, carbon emissions and sinks, built-up land and infrastructure, extraction of fish and timber, agricultural expansion and intensity, climate change, fragmentation and nitrogen deposition and loads. In this context, land-use, land-use intensity and land-cover accounts provide important information on the extent of ecosystem types and the area lost through conversion. These kinds of integrated analysis will be facilitated if relevant units (e.g., major land-cover types such as forests, grasslands) can be directly linked to economic units.

4.108 Biodiversity accounts may also be relevant in the analysis of ecosystem services, particularly in terms of assessing expected ecosystem services flows. For provisioning services, species are harvested directly for food, fibre, timber or energy. Changes in the abundance of species due to human extractive activities would be reflected in species abundance and status. Harvesting in excess of a species' capacity to regenerate (i.e., unsustainable harvesting) would result in lower yields and reduced economic profit and a higher risk of extinction, and would be reflected in a movement towards higher-risk categories in an account focused on species status.

4.109 Species that provide regulating ecosystem services, such as mangrove species (in the form of flood protection) and bees (in the form of pollination), can also be linked to the species biodiversity and land-cover accounts. For mangroves, the level of ecosystem service would be a function of the location, extent and condition of mangroves, information on which could be derived from land-cover and land-use accounts. For bees, the level of pollination service would be a function of the abundance of bees, information on which could be drawn from an account focused on species abundance.

4.110 Independent of their use in ecosystem accounting, the biodiversity accounts described here and land-use and land-cover accounts described in the SEEA Central Framework can be used to track progress towards achieving policy targets such as those concerning the protection of threatened species or ecosystems (or habitats), the sustainable use of harvested species, the maintenance and improvement of ecosystem condition and capacity, and the location of the benefits arising from the use of biodiversity.

4.111 In this broader context, accounting for biodiversity recognizes biodiversity's importance to people, as articulated in several international agreements. Perhaps the most important of these is the Convention on Biological Diversity,[44] which entered into force in 1993. The Convention has three main objectives: (a) the conservation of biological diversity, (b) the sustainable use of the components of biological diversity and (c) the fair and equitable sharing of the benefits arising from the utilization of genetic resources.

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44 United Nations, *Treaty Series,* vol. 1760, No. 30619. Available from http://www.cbd.int/convention/text/.

4.5.2 Measurement of biodiversity

4.112 A wide range of techniques is used to measure biodiversity. It is not the intent of this publication to provide a full review of those techniques but simply to note that biodiversity measurement is a specialist field, that different methods for assessing biodiversity provide varying levels of accuracy and precision, and that, because of the complexities of biodiversity measurement, the focus is placed on selected indicators of biodiversity rather than on accounting for all aspects of biodiversity.

4.113 Biodiversity indicators measure part of the ecosystem or capture a range of dimensions of the system within single measures. Pursuant to the recommendations adopted by the Subsidiary Body on Scientific, Technical and Technological Advice at its ninth meeting, held at Montreal, Canada, in November 2003, the Conference of the Parties to the Convention on Biological Diversity at its seventh meeting, held in Kuala Lumpur in February 2004, agreed on the list of provisional indicators for assessing progress at the global level towards the 2010 biodiversity target that can be implemented worldwide or at national or regional scales.[45]

4.114 The four indicators concerning the state of biodiversity that emerged from these discussions are:

(a) Trends in extent of selected ecosystems;

(b) Trend in abundance and distribution of selected species;

(c) Trend in status of threatened species;

(d) Change in genetic diversity.

4.115 The first indicator describes the remaining ecosystem types in terms of size, the second relates to the average quality of these ecosystem types (mean abundance of species characteristic of these ecosystems as compared with the reference condition) and the third reflects the variability within mean species abundance, focusing on those species that are threatened. Together, these three indicators reflect the degree of homogenization, the core process of biodiversity loss as described in section 2.1.

4.116 Figure 4.2 summarizes the changes in ecosystems, in the abundance of species and in the threat of extinction over time. It shows three points in time for habitat extent (the nested squares in the lower right of the diagram). In the middle, the consequences of habitat loss in terms of change in species abundance are shown, with the dotted lines representing a composite state index which is calculated referring to a benchmark time (or reference condition). At the top, high risk of species extinction is indicated by assessment of species as Threatened, Extinct in the Wild, or Extinct in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species.

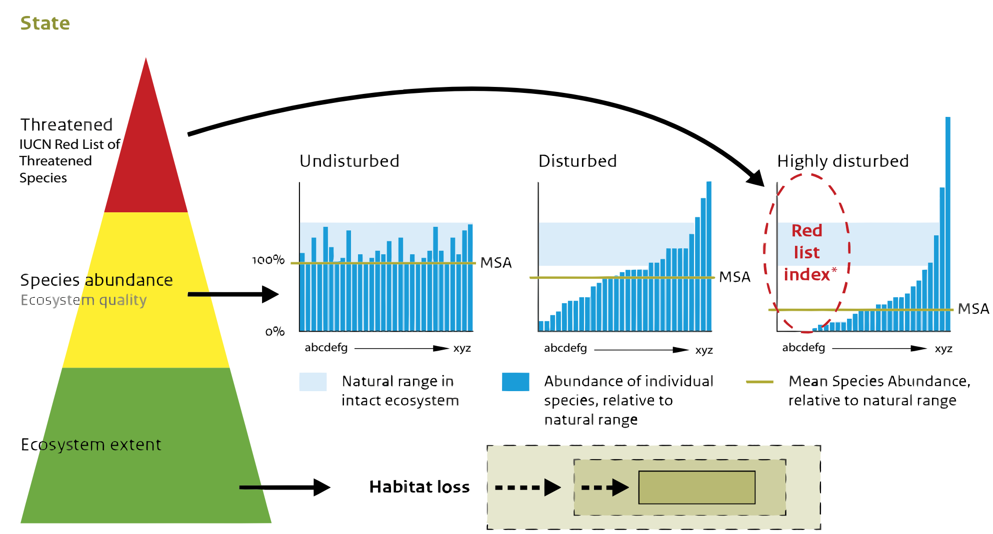
4.117 Producing accounts in physical terms (e.g., hectares) showing the area of different ecosystems in protected areas is a straightforward first step towards accounting for biodiversity (e.g., using the land-cover and land-use accounts of the SEEA Central Framework) and these can also be linked to environment protection expenditure (a response indicator). It is necessary to account for the extent and condition of ecosystems outside of protected areas (i.e., the entire country), since in most countries much of the biodiversity exists outside of those areas.

4.118 For some purposes, more precise information about where, why and how the changes in ecosystem extent occurred are needed. This is of special importance if one is to combine

45 See UNEP/CBD/COP/7/21, annex, decision VII/30. Available from https://www.cbd.int/doc/decisions/cop-07/cop-07-dec-21-en.pdf.

the measurements of changes in condition and the measurements of changes of extent into one common evaluation for purposes of setting policy priorities. To achieve this, both extent and condition measures need to refer to the EAU.

Figure 4.2
Change in ecosystem extent, original species abundance and risk of extinction



* Species assessed as Threatened of Extinct on the IUCN Red List of Threatened Species.

Source: ten Brink, B.J.E., S. Condé and F. Schutyser (2010), figure 9.

4.119 Measurement of biodiversity by species number and abundance can be achieved directly. However, because this approach is costly for large areas, biodiversity is usually estimated through the application of a range of data and methods, including modelling techniques based on information about land cover, land use, fragmentation, climate change and other pressures (Scholes and Briggs, 2005; Alkemade and others, 2009).

4.120 At international and national levels, the state of biodiversity can also be shown via composite indices. Examples of this approach for aggregate measurement of biodiversity include the Red List Index (IUCN, 2014), the natural capital index (ten Brink and Tekelenburg, 2002), the GLOBIO mean species abundance index (Alkemade and others, 2009), the living planet index (Loh and others, 2002; 2005), the biodiversity intactness index (Scholes and Biggs, 2005) and the Norwegian Nature Index (Certain and others, 2011). These composite indicators are the fruit of a long tradition in ecology of expressing complex changes in species abundance through indices.

4.5.3 Structuring information on species and groups of species

4.121 The term "species" can be defined in a number of ways. A species is commonly defined as a group of organisms capable of breeding and producing fertile offspring. However, this definition does not work well for some groups of organisms (e.g., bacteria) and the definition ultimately used depends on the nature of the organism of interest (de Queiroz, 2005). Species are commonly classified according to the taxonomy established by Linnaeus (1758), which continues to evolve.[46]

46 See, for example, the website of the International Commission on Zoological Nomenclature (http://iczn.org); and the International Code of Botanical Nomenclature (Vienna Code), available from http://ibot.sav.sk/icbn/main.htm.

4.122 The biodiversity of species can be measured by their abundance, richness and distribution. Broad-scale assessments of biodiversity are typically based on species richness (i.e., the number of different animal species in an area) or on the richness of endemic species. In this latter measure, the species known to exist in particular areas are listed as present or absent. These data are more readily available than abundance data (i.e., estimated number of animals for each species of animal) and can be measured against the original number of different species in the area. The assessment of species richness is often used but is more suitable for subnational-scale assessments (e.g., for biodiversity "hotspots") and can be used to detect regional shifts in species distributions and local extinctions.

4.123 At a larger (e.g., national) scale, species richness may show little change, and hence measures thereof are often difficult to interpret and relate to human activities. Consequently, it may be necessary to augment species richness data with information from other sources on the importance of particular species to a region, for example, by determining whether the species detected in an area are assessed as Threatened, Extinct in the Wild, or Extinct in the IUCN Red List of Threatened Species.

4.124 It is thus beneficial if assessment of biodiversity of areas includes estimates of species abundance, although these data are usually available only for a limited number of species. Abundance may be measured in absolute terms, by, for example, the total number of individuals of a species or density per hectare. It can also be measured through the establishment of broad classes related to absolute measures categories, for example, "very abundant", "abundant", "common", "rare" and "very rare". Abundance may also be measured in relative terms, in particular as current abundance relative to the past (a benchmark or reference condition). If a species is less abundant now than in the past, it may be at risk of extinction. Species differ in respect of their natural abundance: for example, among mammals, small rodents are naturally very abundant, while elephants and other large slow-breeding mammals are much less abundant.

4.125 Collation of information on species in databases should be a precursor to preparation of biodiversity accounts. For structuring information on biodiversity and in order to create accounts for particular areas (e.g., ecosystem accounting units), it is imperative that the data be referenced spatially and temporally (i.e., by time period).

4.5.4 Species richness and species abundance accounts

4.126 Accounts may be prepared for individual species or groups of species. While accounts for individual species are relatively few in number, accounts of this type may be prepared for some species that are of particular interest, for example, because they are harvested for food and materials, or have iconic values. Such accounts, for example, for fish and timber, are similar to those described in the SEEA Central Framework and are not described further here.

4.127 Table 4.7 presents the general form of a biodiversity account for species abundance. It may be compiled in terms of both absolute and relative abundance. The account follows the general form of asset accounts in the SEEA Central Framework, with opening stock and closing stock. In this account, a net change is shown, but it would be possible to add rows showing the positive and negative changes that result from natural processes or human activity. The accounting period is one year.

Table 4.7
Biodiversity account: species abundance by Kingdom for an EAU

	Animals										
	Mammals	Birds	Reptiles	Amphibians	Insects	Fish	Invertebrates	**Subtotal**	Fungi	Protista	Plants
Opening population											
Closing population											
Net change											
Reference population											
Opening population as proportion of reference population											
Closing population as proportion of reference population											
Net change											

Note: The Kingdoms shown in the table are those proposed by Robert Whittaker in 1969. The Kingdom Animalia is divided by class but not all the classes of animals are shown in the table. The selection of classes and Kingdoms is indicative only and, as appropriate, data may be disaggregated by class or by finer levels (e.g., order and genus) depending on the availability of data and the information requirements. The Kingdom Monera (single-celled organisms without a nucleus (e.g., bacteria)) is not listed, as it is generally not anticipated to become a focus of biodiversity accounting as described here.

4.128 The reference condition of species can refer to any time period, but ideally it should refer to an ecosystem subject to minimal human influence. While such a baseline can be difficult to establish, it does have the distinct advantage of allowing the relative abundances of different species, and of species within different ecosystems within one country and in different countries, to be compared.

4.129 It is important that species from all Kingdoms (i.e., divisions of living organisms) be included in the accounts for species abundance to ensure that the accounts are as representative as possible.[47] However, in practice, the species included in the accounts will need to constitute a representative sample from those Kingdoms, since collecting data on the abundance of all species is resource-intensive and some Kingdoms are better known than others (animals being the best known). The sample of species should include species that are of importance to the ecosystem being measured and priority should also be given to species that are known to be sensitive to human impacts (i.e., responsive to key drivers and pressures).

4.130 Ideally, the basic statistics should be compiled at a BSU or LCEU level and aggregated to form estimates at the EAU level. However, in practice, it is likely to be necessary to work with data at relatively high spatial levels.

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47 A likely exception is the Kingdom Monera (single-celled organisms without a nucleus (e.g., bacteria)). The species within this Kingdom are not anticipated to become a focus of biodiversity accounting as described here.

Annex A4.1

Additional detail concerning accounting for carbon

A4.1 The rationale for carbon accounting in the context of ecosystem accounting was discussed in section 4.4. The present annex provides some additional details on the structure and accounting entries related to the carbon stock account as presented in table 4.6.

A4.2 The carbon stock account presented in that table provides a complete and ecologically grounded articulation of carbon accounting based on the carbon cycle and, in particular, the differences in the nature of specific carbon reservoirs. Opening and closing stocks of carbon are recorded, together with the various changes occurring between the beginning and end of the accounting period recorded as either additions to or reductions in the stock.

A4.3 Carbon stocks are disaggregated into geocarbon (carbon stored in the geosphere) and biocarbon (carbon stored in the biosphere, in living and dead biomass and in soils). Geocarbon is further disaggregated into: oil, gas, coal resources (fossil fuels) and rocks and minerals (e.g., carbonate rocks used in cement production, methane clathrate and marine sediments). Where the information generated from the accounts is policy-focused, the priority should be given to reporting those stocks that are being impacted by human activity (e.g., fossil fuels).

A4.4 Biocarbon is classified by type of ecosystem, at the highest level, terrestrial, aquatic and marine, as shown in table 4.6. This high-level classification can be further broken down, but at present there is no internationally agreed classification of ecosystems. In its absence, compilers may choose to use the land-cover classification of the SEEA Central Framework, although this classification is not specifically designed for ecosystem accounting. Work on land-cover and ecosystem classifications is in the research agenda.

A4.5 A key requirement of carbon accounting is the ability to understand the degree of human influence over particular ecosystems. In this regard, it may be desirable to distinguish the varying degrees of human modification of ecosystems and introduce these distinctions into a classification. A framework for defining the varying degrees of human modification may be structured to encompass, for example:

- Natural ecosystems, which are largely the product of natural and ongoing evolutionary, ecological and biological processes. The key mechanism of "management" in natural ecosystems is natural selection operating on populations of species, which has the effect over time of optimizing system-level properties and the traits of component species. System-level properties that are naturally optimized with respect to, among other things, environmental conditions include canopy density, energy use, nutrient cycling, resilience and adaptive capacity. Natural processes dominate natural ecosystems, which also enable human, cultural and traditional uses. Natural ecosystems include terrestrial and marine ecosystems.
- Semi-natural ecosystems, which are human-modified natural ecosystems, yet natural processes, including regenerative ones, are still in operation to varying degrees. However, the system is often prevented from reaching ecological maturity or is maintained in a degraded state owing to human disturbance and land use. Thus, the structure of vegetation may indicate the absence of natural optima, and the taxonomic composition may reflect depauperate conditions.
- Agricultural ecosystems, which are human-designed, -engineered and -maintained systems on agricultural lands where animals and crops are grown mainly for food, wood and fibre and as feedstocks for biofuels and other materials. Plan-

tations of trees for timber or fruit production (e.g., orchards) are included in agricultural ecosystems.

- Other ecosystems, including settlements and land with infrastructure.

A4.6 The atmosphere and oceans are the receiving environments for carbon released from primary reservoirs and for its accumulations in the economy. In this regard, the treatment of the atmosphere and oceans may be similar to that of the rest of the world in physical supply and use tables in the SEEA Central Framework, since they are not under the control of a particular owner. Oceans may be divided into shallow and deep ocean reservoirs.

A4.7 Accumulations in the economy, which are the stocks of carbon in anthropogenic products, are further disaggregated into the following SNA components: fixed assets (e.g., concrete in buildings, bitumen in roads); inventories (e.g., petroleum products in storage, excluding those included in agricultural ecosystems); consumer durables (e.g., wood and plastic products); and waste. Accounting for waste follows the conventions of the SEEA Central Framework, where waste products (e.g., disposed plastic and wood and paper products) stored in controlled landfill sites are treated as part of the economy.

A4.8 Carbon stored through geo-sequestration (i.e., the managed injecting of gaseous CO_2 into the surface of the Earth) is treated similarly, as a flow within the economy (resulting in an increase in accumulations). Any subsequent release of carbon to the environment is treated as a residual flow with a reduction in accumulations in the economy matched by a corresponding increase in carbon in the atmosphere.

A4.9 Although this is not shown in the table, the ecosystem types described above could be disaggregated further into marine and terrestrial ecosystems. Marine ecosystems include mangroves, salt marshes and seagrass beds. Peat stocks and flows align with the biocarbon sector, with peatland vegetation being associated with a variety of ecosystems, including forests, grasslands, moss beds, mangroves, saltmarshes and paddies. There is potential for further disaggregating geocarbon and biocarbon.

A4.10 The presentation of the row entries in the account follows the basic form of the asset account in the SEEA Central Framework; the entries being opening stock, additions, reductions and closing stock. Additions to and reductions in stock have been split between managed and natural expansion and contraction. Additional rows for imports and exports have been included, thus making the table a stock account, as distinct from an asset account.

A4.11 There are six types of additions in the carbon stock account:

- Natural expansion, which reflects increases in the stock of carbon over an accounting period due to natural growth. Effectively, this will be recorded only for biocarbon and may arise from climatic variation, ecological factors such as reduction in grazing pressure, and indirect human impacts such as the CO_2 fertilization effect (where higher atmospheric CO_2 concentrations cause faster plant growth).
- Managed expansion, which reflects increases in the stock of carbon over an accounting period due to human-managed growth. This will be recorded for biocarbon in ecosystems and accumulations in the economy, in inventories, consumer durables, fixed assets and waste stored in controlled landfill sites, and also includes greenhouse gases injected into the earth.
- Discoveries of new stock, encompassing the emergence of new resources added to a stock, which commonly arise through exploration and evaluation. This applies mainly—and perhaps exclusively—to geocarbon.

- Upward reappraisals, which reflect changes due to the use of updated information permitting a reassessment of the physical size of the stock. The use of updated information may require the revision of estimates for previous periods so as to ensure a continuity of time series.

- Reclassifications of carbon assets, which will generally occur in situations where another environmental asset is used for a different purpose. For example, increases in carbon in semi-natural ecosystems following the establishment of a national park on an area previously used for agriculture would be offset by an equivalent decrease in agricultural ecosystems. In this case, it is only the particular land use that has changed, that is, reclassifications may have no impact on the total physical quantity of carbon during the period in which they occur.

- Imports are recorded to enable accounting for imports of produced goods (e.g., petroleum products). Imports are shown separately from the other additions so that they can be compared to exports.

A4.12 There are six types of reductions recorded in the carbon stock account:

- Natural contractions, which reflect natural losses of stock during the course of an accounting period. They may be due to changing distribution of ecosystems (e.g., a contraction of natural ecosystems) or biocarbon losses that might reasonably be expected to occur based on past experience. Natural contraction includes losses from episodic events including drought, some fires and floods, and pest and disease attacks, and also includes losses due to volcanic eruptions, tidal waves and hurricanes.

- Managed contractions, which are reductions in stock due to human activities and include the removal or harvest of carbon through a process of production. This includes mining of fossil fuels and felling of timber. Extraction from ecosystems includes both those quantities that continue to flow through the economy as products (including waste products) and those quantities of stock that are immediately returned to the environment after extraction because they are unwanted—for example, felling residues. Managed contraction also includes losses as a result of a war, riots and other political events; and technological accidents such as major toxic releases.

- Downward reappraisals, which reflect changes due to the use of updated information that permits a reassessment of the physical size of the stock. The reassessments may also relate to changes in the assessed quality or grade of the natural resource. The use of updated information may require the revision of estimates for previous periods to ensure a continuity of time series.

- Reclassifications, which generally occur in situations where another environmental asset is used for a different purpose. For example, decreases in carbon in agricultural ecosystems following the establishment of a national park on an area used for agriculture would be offset by an equivalent increase in semi-natural ecosystems. In this case, it is only the particular land use that has changed; that is, reclassifications have no impact on the total physical quantity of carbon during the period in which they occur.

- Exports are recorded to enable accounting for exports of produced goods (e.g., petroleum products). Exports are shown separately from the other reductions so that they can be compared to imports.

- Catastrophic losses, which are not shown as a single entry but are allocated between managed contraction and natural contraction. Catastrophic losses in managed contraction would include fires deliberately lit to reduce the risk of uncontrolled wild fires. For the purposes of accounting, reductions due to human accidents, such as rupture of oil wells, would also be included under managed contraction. Catastrophic losses could, however, be separately identified.

Annex A4.2

Additional detail concerning accounting for biodiversity

A4.13 A definition and description of biodiversity in the context of ecosystem accounting have been provided in sections 2.1 and 4.5, which highlight the strong links between the measurement of biodiversity and ecosystem accounting and explain the potential for developing accounts for species as part of developing indicators of ecosystem condition. The present annex provides additional detailed information on the measurement of the link between ecosystems and biodiversity, and further discussion on the measurement of species, including the derivation of indices from species abundance accounts and the compiling of accounts for threatened species.

Geographical extent of ecosystems and biodiversity

A4.14 There is a strong relationship between the extent of ecosystems, land use and biodiversity. Measures of ecosystem condition and extent were covered in more detail in the body of chapter IV; and to the extent that ecosystems are approximated by land cover, the land-cover accounts described in the SEEA Central Framework are relevant.

A4.15 The relationship between land cover and land use varies from case to case. At times, they may appear relatively synonymous concepts: for example, the term "cropland" (e.g., an area covered by wheat) not only refers to land use but also gives an indication of the type of land cover. However, in other cases, land use and land cover are not closely related: for example, a forest may be used for conservation (e.g., protection of species and recreation) or forestry (i.e., to produce timber for sale).

A4.16 Land set aside (used) for conservation is of particular relevance for biodiversity accounting. It is usually the case that using land for conservation has the express purpose of protecting biodiversity and providing opportunities for people to enjoy the environment and the biodiversity of species within it, as well as implicitly enabling provision of ecosystem services from the areas set aside for conservation.

A4.17 Most countries have information on the area covered by national parks and other types of protected areas (e.g., according to the IUCN protected area categories[48]), which has been consolidated in the World Database on Protected Areas.[49] In addition, the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention) (1971)[50] currently lists just over 2,100 wetlands of international importance, covering nearly 2 million square kilometres.

A4.18 Accounts in physical terms (e.g., hectares) showing the area of different ecosystems in protected areas is a straightforward first step towards accounting for diversity (e.g., using the land-cover and land-use accounts of the SEEA Central Framework) and these can also be linked to associated environment protection expenditure (a response indicator). It is also necessary to account for the extent and condition of ecosystems outside of protected areas (i.e., the remainder of the country), since in most countries much of the biodiversity exists outside of those areas. Measurement of the condition of biodiversity, by species number and

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48 For more information, see Dudley, ed. (2008). Also available from http://data.iucn.org/dbtw-wpd/edocs/PAPS-016.pdf.

49 http://www.wdpa.org.

50 United Nations, *Treaty Series*, vol. 996, No. 14583. As amended by the Protocol of 3.12.1982 and the Amendments of 28.5.1987. Available from http://www.ramsar.org/cda/en/ramsar-documents-texts-convention-on/main/ramsar/1-31-38%5E20671_4000_0__.

abundance, can be achieved directly. However, because this approach is costly for large areas, biodiversity condition is usually estimated using a range of data and methods, including modelling techniques based on information about land cover, land use, fragmentation, climate change and other pressures (Scholes and Briggs, 2005; Alkemade and others, 2009).

A4.19 For some purposes, more precise information about where, why and how the changes in ecosystem extent occurred are needed. This is of special importance if one is to combine measures of changes in quality and measures of changes of extent into one common evaluation for purposes of establishing policy priority. For this to be achieved, both extent and quality measures need to refer to an EAU.

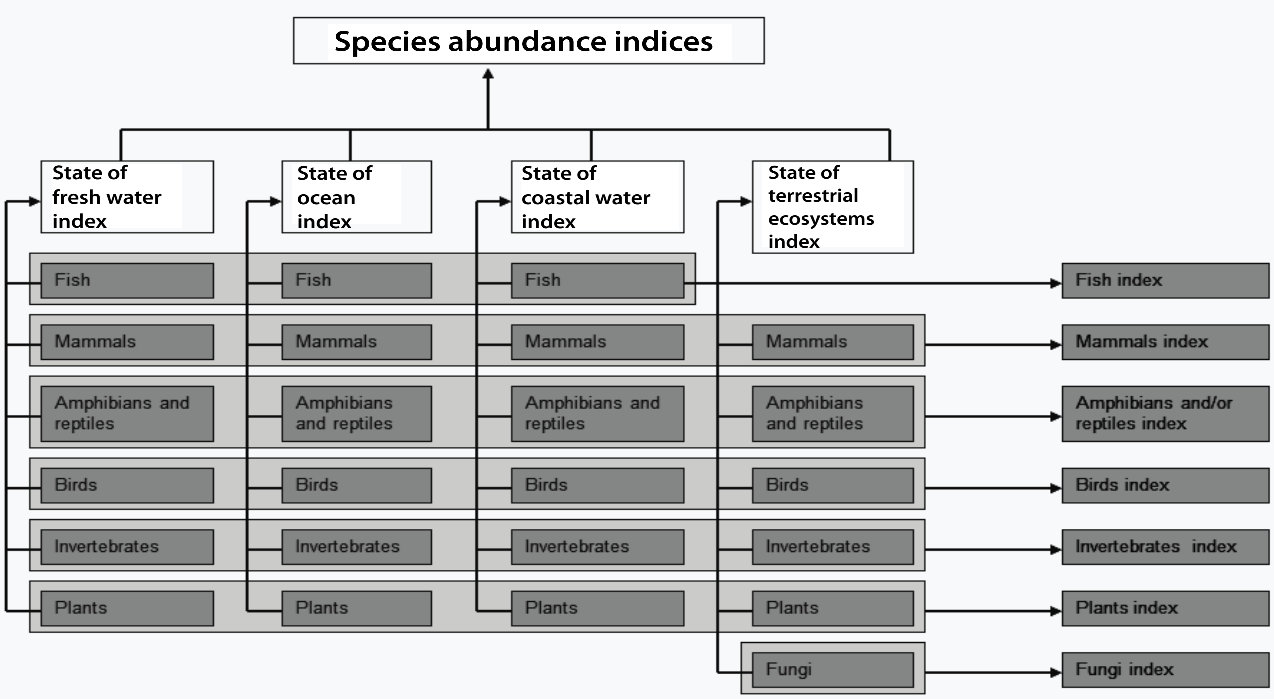
Deriving indices from accounts of species abundance

A4.20 The index methods used for economic indicators, such as the consumer price index (CPI) involving the measurement of changes in a selected basket of goods and services, provide an approach to constructing species abundance indices from the accounts presented above. For the CPI, the weights used are the average consumption of the different goods and services.

A4.21 Biodiversity indices are more complicated, but, usually, area (extent) is one component. Further, ensuring that each trophic level maintains equal weights implies that all parts of the ecosystem are appropriately represented (Skarpaas, Certain and Nybø, 2012).

A4.22 Changes in a total biodiversity index may be explained through a disaggregation into different thematic indices. Figure A4.2.1 shows how it might be possible to aggregate the measures of species abundance by domain (i.e., freshwater, ocean, coastal or terrestrial ecosystem) or species group (i.e., fish, mammals, etc.) so as to derive an overall index of biodiversity or species abundance.

Figure A4.2.1
Possible aggregation of a national nature index for mean species abundance



Accounts for threatened species (extinction risk)

A4.23 The risk of extinction is a function of the natural population dynamics, distribution and abundance of species, environmental change, and human activities directly or indirectly influencing population abundance. In this respect, the more a species is widely distributed and abundant and the higher its reproductive rate, the less likely it is to become extinct. Some species are naturally rare, have limited distributions or low reproductive rates and hence are more susceptible to extinction. The IUCN Red List categories of the IUCN Red List of Threatened Species (IUCN Species Survival Commission, 2012) take these factors and others into account in determining the overall status of species.

A4.24 Accounts showing the risk of extinction can be constructed using the status of species as defined by IUCN Red List categories and related criteria (table A4.2.1), recognizing that changes in status may result from changes in knowledge as well as from genuine changes in biodiversity. Those categories are the following:

- *Extinct*: a taxon is extinct when there is no reasonable doubt that the last individual has died. *Extinct in the wild*: a taxon is extinct in the wild when it is known to survive only in cultivation, in captivity or as a naturalized population (or populations) well outside the past range.
- *Critically endangered*: a taxon is critically endangered when it is considered to be facing an extremely high risk of extinction in the wild.
- *Endangered*: a taxon is endangered when it is considered to be facing a very high risk of extinction in the wild.
- *Vulnerable*: a taxon is vulnerable when it is considered to be facing a high risk of extinction in the wild.
- *Near threatened*: a taxon is near threatened when it is close to qualifying for, or is likely to qualify for, a threatened category in the near future.
- *Least concern*: a taxon is least concern when it is widespread and abundant.
- *Data deficient*: a taxon is data deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status (data deficient is therefore not a category of threat).
- *Not evaluated*: a taxon is not evaluated when it has not yet been evaluated against the IUCN threat criteria.

A4.25 The threatened species accounts record only the presence or absence of species in a particular area.

A4.26 Threatened species accounts may be prepared for countries as a whole or for particular areas or ecosystems within countries. The degree of effort needed to prepare the account increases with the number of areas for which accounts are prepared.

A4.27 It is important to note that, in national and subnational accounts, a status derived from the IUCN Red List relates to an assessment of the species in the entire world, not to the country and area in question. Therefore, species might be assessed against different criteria at smaller scales.

Table A4.2.1
Accounts for threatened species

	IUCN Red List categories								
	Extinct	Extinct in the wild	Critically endangered	Endangered	Vulnerable	Near threatened	Least concern	Data deficient or not evaluated	**Total**
Opening stock									
Additions									
From lower threat categories									
From higher threat categories									
Discoveries of new species									
Rediscoveries of extinct species									
Reclassifications									
Updated assessments									
New additions to list									
Total additions									
Reductions									
To lower threat categories									
To higher threat categories									
Reclassifications									
Local extinction									
Updated assessments									
Total reductions									
Closing stock									

Chapter V

Approaches to valuation for ecosystem services and ecosystem assets

5.1 Introduction

5.1 The valuation of ecosystem services and ecosystem assets is a complex undertaking. In a purely accounting context, the complexity exists because, generally, they are not traded on markets in the same way as other goods, services and assets. Consequently, economic principles must be applied to estimate the prices for the various ecosystem 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.

5.2 In a broader context, valuation is complex because it raises a range of ethical and cultural considerations. Attempts to place values on ecosystems in monetary terms may be considered inappropriate and potentially misleading. This being the case, decisions to undertake the valuation of ecosystems and the estimated valuations themselves commonly generate the most contention among all measurement issues. Notwithstanding these concerns, there is considerable interest in such valuation.

5.3 Often, there is a lack of understanding of the technical and practical complexities involved in valuation, particularly as they pertain to valuation for accounting purposes. Consequently, the aim of the present chapter is to outline: (a) the various motivations for valuation in monetary terms, (b) the various valuation concepts and principles that may be applied, (c) the System of National Accounts (SNA) valuation principles that are relevant when the intent in valuation is to compare ecosystem valuations with existing national accounts valuations and (d) the range of possible valuation methods and associated measurement challenges. A specific objective of this chapter is to enable compilers and analysts of ecosystem accounts to make decisions regarding valuation, while remaining aware of the required assumptions and their implications for interpretation.

5.2 Motivations for valuation in monetary terms

5.4 A number of motivations exist for the valuation of ecosystem services and ecosystem assets, based on the purpose of analysis and the context for the use of valuations in monetary terms. The different motivations point to different requirements in terms of concepts, methods and assumptions. Often, valuation is dismissed or utilized without careful consideration of the relationship between the purpose of analysis and the choice of valuation concepts and methods. The present section describes the key factors that should be taken into account in deciding whether to undertake valuation and what concepts and methods can be applied.

5.5 Many are interested in the analysis of specific policy scenarios and alternatives, in the evaluation of specific projects, for example, cost-benefit analysis, or in the assessment of compensation and damage claims. Others are interested in making estimates of the value of ecosystem services and assets that can be used for comparisons with valuations presented in the standard national accounts or to possibly augment the standard national accounts using alternative measurement boundaries. Examples in this regard include comparisons of the values of environmental assets (including ecosystems) with those of other asset types (e.g., produced assets), and the derivation of degradation-adjusted economic aggregates. Generally speaking, there is also a motivation to raise awareness of the potential significance of ecosystem-related concerns.

5.6 In the consideration and design of policies and projects, and assessment of compensation and damages, it is common practice to value the various costs and benefits of different options. Usually, in decisions made by Governments at all levels, the assessments of costs and benefits take into account the impacts not only on various individual enterprises and households but also on the broader community and, in the context of ecosystems, the broader environment. While impacts upon employment and expenditures may be estimated straightforwardly from market-based valuations, valuation of the effects in the social and environmental domains is typically more challenging. Nonetheless, for the purposes of assessing specific policy choices (e.g., regarding where to build a hospital or whether to install lighthouses or restore polluted wetlands), considering social and environmental factors when estimating the relevant costs and benefits is important. Hence non-market valuation strategies are needed.

5.7 Non-market valuation strategies are also needed in cases where comparison with, or augmentation of, standard national accounting estimates is the motivation for valuation. In this case, an important first step is to recognize that the SNA does not record externalities that arise through economic or other human activity, whether they are positive externalities (e.g., the ecosystem service of flood protection) or negative externalities (e.g., the degradation of river systems through pollution).[51] The focus of valuation is thus on the estimation of non-market values for ecosystem services and ecosystem assets that are not recorded in the SNA, and the alignment of these estimates with valuations already recorded in the SNA.

5.8 For SEEA Experimental Ecosystem Accounting, the focus is on estimating valuations that permit consistent comparison with, or augmentation of, valuations reflected in the SNA. To this end, the alternative valuation strategies that are used should generate estimates that are consistent with the valuation principles of the SNA.

5.9 There are important implications associated with the linking of a specific type of aim with a specific type of valuation concept. In broad terms, two related but different valuation concepts are available. The first concept, that of welfare economic values, entails obtaining valuations that measure the change in the overall costs and benefits associated with ecosystem services and assets. The second concept, that of exchange values, entails obtaining valuations of ecosystem services and assets that are consistent with values that would have been obtained if a market for the ecosystem services or assets had existed. The distinctions between these two valuation concepts are outlined in detail in the following section.

5.10 Since there are likely to be clear-cut differences between the estimated valuations obtained by applying each of these concepts, it is important that the motivation for and purpose of analysis be aligned with the choice of valuation concept. In addition, there is a range of different valuation methods that may be used and, it may be possible that a selected method may be capable of estimating values according to either conceptual approach. Thus,

51 See the 2008 SNA, para. 2.23.

it is not only the choice of concept and method that must be considered but also how the method is applied.

5.11 Each of the following sections examines a specific issue. Section 5.3 discusses alternative valuation concepts; section 5.4 discusses the valuation principles of the SNA; and section 5.5 describes a range of approaches to valuation and their application to the valuation of ecosystems depending on the chosen valuation concept. Section 5.6 considers some particular measurement issues associated with undertaking the valuation of ecosystem services and ecosystem assets, giving particular attention to four key sources of uncertainty which impact valuation exercises.

5.12 Since the focus in SEEA Experimental Ecosystem Accounting is on valuations that permit comparison with and augmentation of valuations in the SNA, the discussion does not encompass a complete examination of all matters pertaining to the valuation of ecosystem assets and ecosystem services. The intent, instead, is to place the estimation of values in monetary terms for the SEEA within the broader context of valuation, and, to the extent possible, improve the general understanding of matters relating to valuation in monetary terms for accounting purposes.

5.13 It is recognized that for other purposes, the choice of alternative valuation concepts and valuation approaches may be more appropriate. In particular, for policy assessment and evaluation, it is likely that the purpose of valuation will be welfare analysis, and thus a welfare economic concept of value is likely to be of most relevance, or an approach that combines both welfare economic and exchange values (e.g., multi-criteria analysis).

5.14 While the valuation concept and approach may vary depending on the purpose of the analysis, the broad targets of valuation—ecosystem services and ecosystem assets—remain constant. Thus, while the focus of valuation for ecosystem accounting described here may not be appropriate for all purposes, ecosystem accounting in physical terms, as described in chapters III and IV is relevant in all situations, and the accounting model described in chapter II provides a coherent and integrated framework for ecosystem assessment, whatever valuation concept is used.

5.3 Valuation concepts

5.3.1 Ecosystem services and assets in relation to public and private goods

5.15 Within the broad context of economic value, it is relevant to consider ecosystem services and ecosystem assets in terms of their contribution to either (a) the value that accrues to individuals (private goods) or (b) the value that accrues to society more broadly (public goods). Since private and public goods possess different characteristics, different approaches to the estimation of relevant prices must be considered.

5.16 Provisioning services are typically related to private goods, whereas many regulating and cultural services have a public goods–type character. Public goods are associated with the principles of (a) non-excludability, meaning that is not possible to deny people the benefit from the ecosystem service concerned and (b) non-rivalry, meaning that one person's enjoyment of an ecosystem service does not diminish the availability of the service to others. Clean air is a typical example of a public good. Ecotourism can be viewed as a "quasi" public good, to the degree that it is non-rivalrous (assuming no overcrowding), but in principle it is excludable (in the case, e.g., where a fence is placed around a particular site and an entrance fee is charged). Depending on the regulatory system, fisheries and forests that provide provisioning services in the form of fish and timber may be common goods, in that they are rivalrous (e.g., fishing by one person reduces the amount of fish available to others) but often not excludable.

5.17 The price mechanism for the provision of public goods is not a well-functioning one: consumers do not have an incentive to pay and producers do not have an incentive to supply. Common goods may also be impacted by extraction above sustainable levels. This situation may reflect the nature of the production environment, for example, the existence of increasing returns to scale and various externalities from production. Consequently, public intervention, most commonly through production by government or through the definition and allocation of property rights, often occurs in order to maintain or create an efficient allocation of such goods. Further, because public goods are not traded in markets, the valuation of such goods requires the application of non-market valuation methods. The discussion of non-market valuation methods is the main focus of section 5.5.

5.3.2 Welfare economic and exchange concepts of value

5.18 In neoclassical welfare economics, the value of a good or service is determined by the demand for and supply of that good or service in a perfectly functioning market, as illustrated in figure 5.1. The figure shows a demand and a supply curve for a good traded in a market in quantity (volume) Q and at price P. The demand and supply curves are assumed to be linear for the purpose of this illustration, but this will not normally be the case in practice.

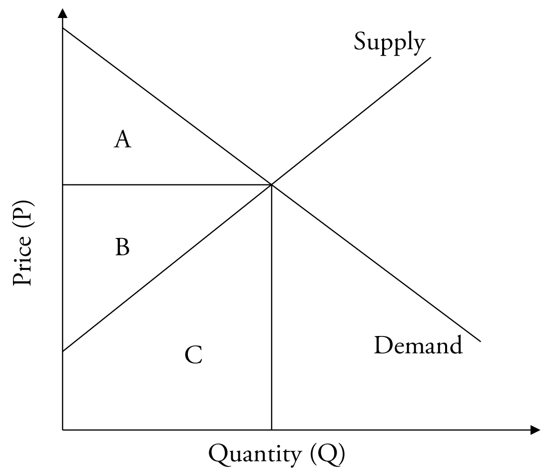
5.19 In figure 5.1, area A represents the consumer surplus, which is the gain obtained by consumers because they are able to purchase a product at a market price that is lower than the highest price they would be willing to pay.[52] The producer surplus, represented by B, is the amount by which producers benefit by selling at a market price that is higher than the lowest price that they would be willing to sell for, which is related to their production costs. Area C can be assumed to represent the production costs, which differ among producers. For the purpose of this chapter, the sum of areas A and B is the surplus, which is the net economic gain resulting from market transactions with a volume Q at price P.

5.20 In the context of comparing values of ecosystem services with values in the national accounts, the objective is to value the quantity of ecosystem services at the market prices that would have prevailed if the services had been freely traded and exchanged. The market price (P) in figure 5.1 reflects consumers' marginal willingness to pay for the ecosystem service with a market equilibrium quantity of Q. In the case of ecosystem services not traded in a market, alternative approaches to establishing a price for the ecosystem, in line with the SNA accounting principles, need to be found. This is further discussed in section 5.5.

5.21 For national accounting purposes, the focus of valuation is on the area of producer surplus plus costs of production, that is, areas B and C. This reflects a concept of exchange value where, while different consumers may have been willing to pay different prices for a good or service, in practice, all consumers pay the same price P. Thus, the total outlays by consumers and the total revenue of the producers is equal to area B plus C or, equivalently, to P times Q. For accounting purposes, this approach to valuation enables a consistent recording of transactions between economic units since the values for supply and use of products are the same.

52 It is to be noted that a distinction exists between individual and aggregate consumer surplus.

Figure 5.1
Consumer and producer surplus



5.22 Rather than focus on an estimated market price and quantity determined by the intersection of market supply and demand, welfare analysis of ecosystem services begins with the construction of a utility function and demand curve for the ecosystem service and then goes on to evaluate the change in area A for a proposed policy. For example, an increase in price of access to a national park would, ceteris paribus, decrease the size of area A and lead to a loss of total consumer surplus. Evaluation of a change in consumer surplus poses the challenge of determining the relevant starting point, or baseline quantity, of the ecosystem service for comparison with the current and prospective quantity of the service. The closer the baseline quantity is to zero, the larger becomes the estimate of consumer surplus (it is potentially infinite).

5.23 Pursuant to this characterization, the difference between the welfare economic concept of value for ecosystem services on which welfare analysis is based, and the national accounts concept of exchange value, lies in the frequent focus of the former on changes in consumer surplus under alternative scenarios. Consequently, given the interest in exchange values for accounting purposes, much of the present discussion on approaches to valuation considers the extent to which consumer surplus is incorporated in the resulting analysis. A critical consideration is that willingness-to-pay measures that are commonly estimated and reported in the literature involve some approaches to the valuation of ecosystem services that utilize not just a constructed market price reflecting exchange values, but also an evaluation of different scenarios and changes in consumer surplus.

Shadow prices

5.24 Shadow prices are commonly used in welfare analysis to evaluate ecosystem services and assets. The market prices for goods and services and the shadow prices for the same goods and services diverge when markets are inefficient and do not properly account for economic, social or physical constraints (e.g., opportunity costs and scarcity) associated with the good or service. Shadow prices are therefore not observable in the market.

5.25 In the context of welfare analysis, shadow prices are theoretically useful for assessing sustainability, given the general lack of efficient markets for ecosystem services and assets. For evaluation of ecosystem services over time, changes in consumer surplus can be estimated by comparing the size of area A under the assumption of market prices (where a related market price can be determined) to the size of area A under the assumption of shadow prices. Where a related market price cannot be determined, shadow prices based on differing assumptions may be compared.

5.26 Shadow prices are aligned with a welfare economic concept of value rather than an exchange value concept. Therefore, even though shadow prices may be considered marginal, they are not equivalent to marginal prices obtained through a market mechanism. Rather, they are marginal in the sense that they reflect the change in welfare associated with a marginal change in the relevant good or service.

Total economic value

5.27 Demand curves, such as that shown in figure 5.1, reflect the fact that different consumers are willing to pay different amounts for different quantities of a particular good or service. These differences reflect variations in the relative importance of a good or service to a consumer. For accounting purposes, where market prices are observed, the individual factors that determine the relative importance of a good or service are effectively ignored. However, in the estimation of prices for non-market goods and services, it is relevant to consider the determinants of consumers' willingness to pay.

5.28 One model that is commonly used in this regard is the total economic value (TEV) framework. In the TEV framework, the value of a good or service encompasses four key dimensions:

(a) *Direct use value*, arising from the direct utilization of ecosystems, for example, through the sale or consumption of a piece of fruit;

(b) *Indirect use value*, stemming from the indirect utilization of ecosystems, in particular through the positive externalities that ecosystems provide, for example, clean air;

(c) *Option value*, relating to people's responses to uncertainty. Because people are unsure about their future demand for a service or the longer-term implications of a current decision, they may be willing to pay now to retain the option of using a resource in the future (e.g., by placing a value on a forest's potential to supply plants for medicinal purposes) or to secure insurance against possible future losses;

(d) *Non-use value*, derived from attributes inherent in the ecosystem itself. Three aspects of non-use value are generally distinguished: existence value (based on utility derived from knowing that something exists), altruistic value (based on utility derived from knowing that somebody else benefits) and bequest value (based on utility from knowing that the ecosystem may be used by future generations). These different types of non-use value may be reflected, for example, in the value of iconic species such as that of the giant panda. The different categories of non-use value are often difficult to separate from each other and from option values, both conceptually and empirically.

5.29 Often, non-market valuation methods focus on estimating particular aspects of value. For example, methods may have a focus on estimating direct use values of a particular ecosystem service.

5.3.3 Aligning valuation concepts with motivations for valuation

5.30 In sections 5.2 and 5.3, a number of motivations for valuation have been described and two distinct valuation concepts—exchange value and welfare economic value—have been introduced. Most commonly in economic and environmental cost-benefit analysis, the focus is on welfare economic values and the use of welfare analysis, since it is the impacts of various policy choices on economic outcomes that are of common interest. This alignment between the motivation for valuation and the choice of the valuation concept is appropriate.

5.31 However, where there is interest in comparing values of ecosystem services and assets with existing national accounting values, it is necessary to use a consistent valuation basis for all entries. Since the basis for accounting is the exchange value concept, it is appropriate to estimate exchange values for ecosystem services and ecosystem assets when the intention is to compare these values with existing entries for production, consumption and wealth. The following section summarizes the valuation principles of the SEEA and the SNA which are based on the exchange value concept.

5.32 In concept, it may be possible to undertake some accounting exercises incorporating valuations for ecosystem services and ecosystem assets that use welfare economic concepts of value. However, this is likely to require a re-estimation of relevant SNA-based accounting valuations with a shift from an exchange value concept to a welfare economic concept of value, perhaps through the estimation of shadow prices. This possibility is explored in approaches such as inclusive wealth accounting where, in concept, shadow prices for all assets (including ecosystems) are compared. In practice, the estimation of shadow prices is a challenging task and market prices (based on exchange value concepts) are often used as proxies for shadow prices.[53]

5.3.4 Objects of valuation in ecosystem accounting

5.33 The two primary components of ecosystem accounting are ecosystem services and ecosystem assets. Chapters II, III and IV have explained in detail the relevant concepts and the various approaches to the measurement of these two variables in physical terms. Some ecosystem services, such as timber, contribute to benefits already in scope of the standard measures of economic activity. A common objective in this situation is to separately identify or partition the part of the market price that is attributable to inputs of ecosystem services from the part that is attributable to other inputs, including produced assets and labour.

5.34 Other ecosystem services contribute to non-SNA benefits. For example, various regulating services generate clean air. For these services, as there is no market price for the benefit that can be partitioned, alternative valuation strategies must be pursued.

5.35 Once estimates of the value of different ecosystem services have been derived, a number of paths may be pursued depending on the analytical and policy questions of interest. First, values for each of the ecosystem services within a given spatial area (e.g., an EAU) can be aggregated. Second, aggregate values can be obtained for a selected ecosystem service or for all ecosystem services across all ecosystem assets in a country. Third, aggregate values can be obtained based on the value of all future flows of ecosystem services, which, following standard approaches to capital accounting, provide an estimate of the overall value of eco-

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53 See, for example, *Inclusive Wealth Report 2012* (United Nations University International Human Dimensions Programme on Global Environmental Change (UNU-IHDP) and United Nations Environment Programme (UNEP), 2012). A particular focus in this report is the potential incorporation of monetary values for regulating and cultural services in inclusive wealth accounting approaches, although such values were not incorporated into the estimates that were prepared.

system assets. Each type of aggregation requires particular assumptions and involves distinct measurement challenges. Consequently, there may not be any interest in compiling all of the potential monetary measures, even if this may be possible theoretically. Relevant assumptions concerning the aggregation of ecosystem services are discussed in section 5.6.

5.36 A particular issue arises in the case of ecosystem assets, since it may not be appropriate to apply valuation approaches developed in the context of produced assets (such as buildings and machines) to ecosystems which are complex assets, have the potential to regenerate over time, provide multiple services, and may experience varying degrees of use over time. A related question is whether the valuation of ecosystem degradation should be based on analysing forgone income due to the reductions in the current and future flows of ecosystem services, or if valuation of ecosystem degradation should be based on the costs of restoring the ecosystem to a previous state. This issue is discussed further in chapter VI.

5.4 Valuation principles in the SEEA and the System of National Accounts (SNA)

5.4.1 Market prices

5.37 In the SEEA, as in the SNA, the values reflected in the accounts are, in principle, based on the current transaction prices or market prices for the associated goods, services or assets that are exchanged (2008 SNA, para. 3.118). Strictly, market prices are defined as amounts of money that willing purchasers pay to acquire goods, services or assets from willing sellers. The exchanges should be made between independent parties on the basis of commercial considerations only, sometimes called "at arm's length" (ibid., para. 3.119).

5.38 Defined in this way, in a perfectly competitive market, at a particular point in time, the same market price will be paid by all purchasers. In practice, market prices used in the national accounts will vary between purchasers; and over time; and hence they should be distinguished from a general market price that gives an indication of the "average" price for exchanges in a type of good, service or asset over a given period of time. In most cases, market prices based on the totality of transactions that actually occur over an accounting period will approximate the general "average" market prices just described.

5.39 In practice, prices are generally impacted by taxes, subsidies and the costs of distributing products to consumers (reflected in transport, wholesale and retail margins). The SNA therefore defines a number of different prices—basic prices, producer prices and purchasers' prices—in terms of different treatments of taxes, subsidies and margins. The distinctions between these different prices should be considered in valuation exercises but are not expanded upon here. For further details, see the SEEA Central Framework, section 2.7, and the 2008 SNA, chapter 6.

5.4.2 Valuation of transactions

5.40 As defined in the 2008 SNA (para. 3.51), a transaction is an economic flow that is an interaction between institutional units (e.g., corporations, households, governments) by mutual agreement or an action within an institutional unit that it is analytically useful to treat like a transaction, for example, household own-account production. A large proportion of transactions are monetary transactions in which one institutional unit makes (or receives) a payment stated in units of currency. Common monetary transactions include expenditure on the consumption of goods and services; payments of wages and salaries; and payments of interest, rent, taxes and social assistance benefits.

5.41 Non-monetary transactions are transactions for which a market price is not observable or does not exist. The value of these transactions must therefore be measured indirectly or otherwise estimated. In some cases, a non-monetary transaction may be clearly observed between institutional units, for example, a barter transaction, and for national accounting purposes, a value should be estimated for recording it in the accounts. In other cases, the entire transaction must be constructed and a value then estimated for it. These constructed transactions are referred to as imputed transactions (2008 SNA, para. 3.75).

5.42 Imputed transactions are recorded when there are flows that are considered analytically useful to treat as transactions. An important imputed transaction in the national accounts is the measurement of consumption of fixed capital (depreciation). This is "constructed", since the flow is internal to an institutional unit and no actual monetary flows occur.

5.4.3 SNA approaches to valuing non-monetary transactions

5.43 When market prices are not observable, valuation according to market price equivalents provides an approximation to market prices. In such cases, market prices of the same or similar items when such prices exist will provide a good basis for applying the principle of market prices, provided the items are traded currently in sufficient numbers and in similar circumstances.

5.44 In using a market price equivalents approach, it is useful to be aware of two (usually unstated) assumptions: first, that the price of the good or service is independent of all other goods and services, or, put differently, that the operation of the market allows prices to take into account a range of interrelated effects; and second, that the equivalent prices being used as proxies have themselves been set in a manner that can be considered incentive-compatible.[54] That is, the market or institutional setting is such that the revealed prices reflect the truthful responses of the market participants.

5.45 Where no sufficiently equivalent market exists and reliable surrogate prices cannot be observed, the SNA identifies a second-best procedure for use, namely, the cost of production approach, in which the value of the non-monetary transaction is deemed to be equal to the sum of the costs of producing the good or service, that is, the sum of intermediate consumption, compensation of employees, consumption of fixed capital (depreciation), other taxes (less subsidies) on production, and a net return on capital (2008 SNA, para. 6.125).

5.46 This approach is most commonly applied in the valuation of the own-account production of enterprises and households and in the valuation of the production of public goods by government units, such as the production of education and health services.[55] This approach to estimating prices effectively reflects a decomposition of a market price into components that are observable and hence amenable to estimation. In relation to figure 5.1, this method measures area C and assumes that the costs of production include a normal return on capital, that is to say, that there is no producer surplus in the production of these outputs.[56]

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54 A scheme or process is said to be incentive-compatible if all of the participants fare best when they truthfully reveal any private information asked for by the mechanism.

55 Strictly speaking, a distinction must be drawn between non-monetary transactions related to market output (e.g., own-account production of households) and those related to non-market output (e.g., production of public goods by government units).

56 For non-market output of government, the costs of production are so defined as to exclude the net return to capital component (see 2008 SNA, para. 6.125).

5.4.4 Valuation of assets

5.47 Assets—strictly economic assets in an SNA context—are stores of value representing a benefit or series of benefits accruing to the economic owner by holding or using the entity over a period of time (2008 SNA, para. 10.8). For economic accounting purposes, the ideal source for asset prices are *values observed in markets*, in which each asset traded is completely homogeneous, is often traded in considerable volume and has its market price listed at regular intervals.

5.48 In some cases, observed market prices may cover the values of a number of assets. For example, prices for real estate will usually include a value both for the dwelling (or buildings) on a piece of land and for the land itself (in particular its size and location). The notion of composite assets is one that is explained further in the SEEA Central Framework, section 5.6, and is of relevance in the context of ecosystems which, by definition, represent a combination of biophysical components.

5.49 When there are no observable prices, an attempt should be made to estimate what the prices would be if a regular market existed and the assets were to be traded on the date to which the estimate of the stock relates. The SNA describes two main approaches to dealing with this situation.

5.50 The first approach entails using the *written down replacement cost* which recognizes that the value of an existing asset (primarily a produced asset), at any given point in its life, is equal to the current acquisition price of an equivalent new asset less the accumulated consumption of fixed capital on the existing asset over its life. (2008 SNA, para. 13.23).

5.51 The second approach entails using the *discounted value of future returns*. For some assets, including many environmental assets, there are no relevant market transactions or set of acquisition prices that would permit the use of the previous approaches. Thus, no values for the asset itself, in situ, are available. In this situation, the discounted value of future returns approach, commonly referred to as the net present value (NPV) approach, uses projections of the future returns from the use (usually extraction or harvest) of the asset. Chapter V of the SEEA Central Framework discusses NPV approaches at length in the context of individual environmental assets, such as mineral and energy resources, timber resources and aquatic resources.

5.52 In the SNA and the SEEA Central Framework, the valuation of assets is limited to those assets over which property rights can be enforced. It is the existence of property rights that generates the potential for a stream of economic benefits which, in turn, give economic assets their exchange value.

5.4.5 The decomposition of value into price, quantity and quality

5.53 The analysis of changes in value over time is an important component of accounting. One way of considering changes in value is to recognize that changes may arise owing to changes in prices or changes in quantity. For national accounting purposes, the decomposition of value into price and quantity components is undertaken within an index number framework, which also provides the basis for the direct measurement of price change (e.g., through the consumer price index). While index number theory is well established, there are a number of options that can be made in selecting any decomposition of values.

5.54 That the items being valued will generally change in quality over time raises a key issue. For example, a new car purchased in 1990 is likely to be quite different in quality from a new car purchased in 2012, even allowing for general features such as engine size and number of seats. Thus, simply tracking the purchase price of a car and using a quantity of one car does not provide a good indication of the decomposition of value change. A reasonable assessment must take into account changes in price, quantity and quality.

5.55 For complex items, such as cars and computers, methods have been developed to make assessments of the changes in quality on an ongoing basis. The hedonic approach, for example, relies on breaking up an item into its various "characteristics". Assessments of the changes in each of the characteristics are then aggregated to form an overall assessment of whether the change in the total value of an item (i.e., the purchase price) is due to changes in quality.

5.5 Valuation of ecosystem services

5.5.1 General considerations for different types of ecosystem services

5.56 Appropriate valuation approaches differ by type of ecosystem service, since different ecosystem services contribute to economic and other human activity and link to benefits and well-being in different ways. Consequently, in order to design a valuation approach for a specific ecosystem service, it is necessary to understand (a) how the service leads to the generation of benefits and (b) the relation between those benefits and the recording of the related economic activity in the SNA.

5.57 In this context, it is relevant to note that in cases where a link to the SNA can be made, that is, where an ecosystem service can be linked to the value of output of an SNA benefit, valuation approaches should focus on determining the contribution of the ecosystem service to the market price of the relevant product rather than on valuing the ecosystem service directly. These are commonly referred to as cases of joint production, where the contributions of multiple inputs are decomposed through analysis of production functions. While seemingly straightforward, these decompositions in fact pose a significant challenge and have their own limitations, conceptually speaking, which are discussed in the following sections.

5.58 Described below are some of the general economic considerations associated with the different types of ecosystem services. Specific approaches to the valuation of quantities of ecosystem services that have been developed are discussed as well.

Provisioning services

5.59 Provisioning services relate to goods extracted from, or harvested in, an ecosystem. Generally, the value of production of these goods is included in the SNA production boundary and hence in GDP. The process of harvest or extraction normally involves costs of human inputs (labour, produced assets, etc.), which need to be deducted from the value of production in the course of deriving the valuation of the relevant ecosystem service. There may be a need to consider the significant impacts of taxes and subsidies on production.

5.60 The usefulness of understanding the value of these ecosystem services lies in enabling the contribution of provisioning services to GDP to be determined. Put differently, it is useful to recognize that if the ecosystem services were not available for use in production, then they would need to be replaced with other factors of production, or production would diminish—or even cease.

5.61 The collection of food or raw materials may take place in an ecosystem uncultivated by humans, but it is more likely that harvesting and extraction will occur in an ecosystem that is modified by people. This modification may take the form of enrichment planting of specific species or of degradation due to past overharvesting. Many ecosystems have been modified to favour the supply of specific services, as is the case for cropland or intensive pastures.

5.62 Harvesting and extraction may occur under different management mechanisms and the valuation of provisioning services will depend on the associated structure of property rights. The ecosystem may be privately owned, with the landowner harvesting ecosystem services. A private owner, or a government, may lease the land to an individual, for instance, a farmer, or to a group of individuals. Or, there may also be communal or government ownership of the ecosystem asset, with restricted or open access to the resources present in the ecosystem. These management mechanisms or institutional arrangements will affect how the costs of maintaining ecosystem services supply are reflected in the relevant economic transactions.

5.63 A private landowner harvesting timber or crops from an ecosystem is likely to have used labour and produced assets to modify the ecosystem and to harvest the resource. The supply curve in figure 5.1, in particular area C, thus reflects the costs involved in harvesting (labour, produced assets (through depreciation costs), intermediate inputs) and the costs associated with the use or modification of the ecosystem (e.g., draining an agricultural field prone to flooding, or pruning trees in a plantation forest).

5.64 When a land user leases land to grow crops, the costs include the costs of leasing the land, with the lease price reflecting the potential to grow crops as a function of acreage, soil fertility, hydrological properties, and perhaps even the presence of local pollinators—in other words, the ecosystem characteristics of the area. In this case, the annual lease price of the land reflects, to a degree, the value of the relevant ecosystem services of which the land user avails himself. However, it needs to be kept in mind that the value of land may reflect several other important factors, for instance, access to markets or speculation on potential increase in future land value due to land development (for instance, when farmland is used for residential development).

5.65 In the case of the extraction or harvest of provisioning services in an ecosystem not owned or leased by the beneficiary, the beneficiary is not paying for the use of the ecosystem asset. An example in this regard is the collection of berries on government-owned land, or fishing in waters that are not regulated or where the purchase of a fishing licence is not required. In this case, the unit resource rent may be used as a proxy for the economic value of the ecosystem service, although there are specific issues to be considered in adopting a resource rent approach which are analysed further below.

5.66 Note that one ecosystem can supply different types of provisioning services: for instance, there may be timber benefits from a forest plot which accrue to the landowner, and the provision of the mushrooms and berries collected on the same plot, which may be free to the public under an open access regime.

Regulating services

5.67 It is somewhat more difficult to achieve the overall valuation of regulating services. Regulating services support and enable economic activities by means of the positive externalities that they generate. For instance, an ecosystem providing flood protection services allows safe habitation, or agricultural activities, in a zone otherwise prone to flooding. Where these services directly affect human well-being, through, for example, positive health impacts due to air filtration, they may generate a value that includes consumer surplus.

5.68 However, many regulating services may contribute to producer surplus, by allowing production to take place or preventing damages to production. For example, flood protection services may allow agricultural production in floodplains. The costs of maintaining the ecosystem or providing the service are generally not incurred by the users of the service, except in the relatively rare cases where mechanisms for payments for ecosystem services (PES) have been established. In cases where there is no PES mechanism in place, those services normally make up part of the producer surplus, meaning that, as a consequence of the regulating services, some producers have more favourable conditions for undertaking specific economic activities than other producers or are not required to take mitigation measures (e.g., construction of flood control structures).

5.69 In cases where the costs of mitigation or adaptation are higher than the producer surplus—where, for example, mechanical flood protection is very expensive—the producer is likely to cease activities when the ecosystem's regulating services are no longer provided. Under these conditions, the producer surplus (represented by area B in figure 5.1) constitutes an estimate of the maximum amount that a producer would pay for the services and thus may be considered a reasonable upper bound of the value of the ecosystem service to the producer. However, it should be recognized that the producer surplus will, in most cases, reflect not only the services provided by ecosystems but other factors as well (e.g., distance to markets and technology) which facilitate production at a lower cost than that borne by competitors.

5.70 For the valuation of regulating services in the absence of markets for ecosystem services, it is necessary to determine consumers' marginal willingness to pay for the service concerned (consumers in this case include intermediate consumers such as agricultural and industrial producers). Commonly, the focus of measurement for regulating services is welfare analysis. Consequently, a number of the valuation methods developed in the field of environmental economics, which include elements of consumer surplus, are used. Without adjustment, however, the estimates obtained may be less applicable in the context of comparing with estimates based on exchange values used in standard economic accounting. A notable exception in this regard is the replacement cost approach (described further below), which may be of particular relevance to the valuation of regulating services.

Cultural services

5.71 For cultural services, the situation differs depending on the service involved. A number of them, like spiritual and symbolic services and information and knowledge services, generate consumer surplus and may be difficult to estimate in terms of exchange values. In certain situations, some types of cultural services may be embedded in the prices of housing and land (and associated rentals)—to the extent that (to take one example) the location of a house providing sea views generates an important amenity value. Nonetheless, differentiating these components of value may still be quite challenging.

5.72 Cultural services related to tourism and recreation, on the other hand, are somewhat different in that they provide both a consumer surplus and a producer surplus. Generally, the economic activities associated with recreation and tourism are in scope of the SNA production boundary. However, as for provisioning services, the specific contribution of the ecosystem is not generally distinguished in this context. The contribution of the ecosystem will vary significantly among different activities—for example, it may be smaller for a restaurant than for, say, a canoe rental firm—as well as among individual firms. For instance, a hotel located adjacent to a national park may attract tourists because of the possibilities for ecotourism, which will not be the case for a hotel in a city centre.

5.73 In order to analyse the monetary value of the ecosystem services that contribute to recreation and tourism, it is therefore necessary to estimate the relative importance of recreational and experiential activities within ecosystems in respect of determining the number of tourists who visit certain areas. Finally, it is to be noted that since the costs for managing natural parks are not normally incurred directly by the economic units providing recreation and tourism activities, the contribution of ecosystems to providing opportunities for recreation is likely to be reflected within the producer surplus of those units.

5.5.2 Approaches to pricing ecosystem services

5.74 Described below are a range of approaches to pricing ecosystem services. Commonly, these approaches are not explicit about the extent to which they are consistent with welfare economic or exchange value concepts. Given earlier discussion, it is therefore important to understand what precisely is being measured and the relevant assumptions so as to ensure that the approach used is appropriate for the intended valuation concept and purpose of valuation.

5.75 In this context, the following general remarks are relevant. First, many approaches to the valuation of ecosystem services focus on the measurement of the direct and indirect use values with relatively fewer methods including the non-use and option value components of total economic value.

5.76 Second, some approaches focus on the extent to which consumers are willing to pay for ecosystem services. In concept, such methods may be adapted to enable estimation of a demand curve for a particular service and from this demand curve, it may be possible to derive an appropriate estimate of exchange values.

5.77 Third, depending on the valuation approach and the design of the valuation exercise, the valuation approaches described in the present section may not take full account of the negative impacts of economic and other human activity on ecosystem assets, that is, ecosystem degradation. For example, use of resource rents to estimate values for ecosystem services may make the assumption (implicitly or explicitly) that the resource is being extracted sustainably. Since this is often not the case, there is a risk that the resulting estimates will understate the "true" value of ecosystem services in terms of capturing all of the relevant missing prices.

5.78 Some valuation approaches have been used to measure the value of degradation separately (e.g., those entailing restoration cost, value of ecosystem resilience, certain revealed preference studies) but more research is needed to either (a) combine these approaches which reflect assumptions regarding future degradation with approaches used to value the current flows of ecosystem services or (b) develop valuation methods that do not require assumptions about current and future use of the ecosystem.

Pricing using the unit resource rent

5.79 Most commonly, the use of this approach to pricing is associated with provisioning services like those related to outputs of the agriculture, forestry and fishing industries, in particular where there are limited or no possibilities for using land leases and prices as an indicator of the price of ecosystem services. In the case of provisioning services, there is usually a measurable human input in terms of both labour and produced assets which is combined with the relevant ecosystem services to produce the benefit. The examples of ecosystem services in chapter III indicate what needs to be considered in defining the links between benefits and ecosystem services for a range of provisioning services.

5.80 Importantly, given the role of human inputs, the price of the benefit—for example, the price of landed fish—should not be used directly as a surrogate price for the ecosystem service, because a part of the benefit price reflects the costs of using labour and produced assets. The difference between the benefit price and the unit costs of labour, produced assets and intermediate inputs constitutes the unit resource rent.

5.81 Under this approach to valuation, the unit resource rent represents an estimated price for the ecosystem service. However, a number of market conditions must be in place for estimates of unit resource rent to constitute accurately a price for the ecosystem services that takes into account the potential for degradation of the resource. These conditions, among others, require that the resource be extracted or harvested in a sustainable way and that the owner of the resource seek to maximize his or her resource rent.

5.82 Often, these conditions are not met. In particular, if there is open access to the resources and no charge by the owner for access, then the marginal unit resource rent will approach zero, thereby implying that the price of the ecosystem service is zero. Thus, whether the resource rent approach to valuing ecosystem services is appropriate will depend on the access conditions in place.[57]

5.83 Although the measurement and analysis of resource rent constitute a well-established field of economics, a review of available methods suggests that there is a general need to develop alternative approaches to analysing the value of ecosystem services in the case where open-access resource management is involved.

Replacement cost methods

5.84 The replacement cost method estimates the value of an ecosystem service based on the costs that would be associated with mitigating actions if it were to be lost. For example, the cost of constructing a water purification plant because the water filtration service of an ecosystem supplying groundwater to an aquifer used for drinking water is impaired. This method does not incorporate any consumer surplus. On the assumption that society would indeed choose to replace the service. In the literature, it is stated that this method can be used, in principle, if the alternative being considered provides the same services and is the least-cost alternative, and if it can be reasonably assumed that society would choose to replace the ecosystem service if it were lost.

5.85 The replacement cost method may be of particular relevance in the case of regulating services such as water purification and flood control.

5.86 A related method is the "costs of treatment" method, which involves estimating the value of an ecosystem service based on the costs of repairing damages that would occur in the absence of the service. This is of particular relevance for regulating services such as erosion and sedimentation control, and air purification. For instance, in the absence of erosion control, the barrier lake of a hydropower dam would receive higher sediment loads, and the costs of removing that sediment can be used as an indicator of the value of the service, under the same conditions of this being an adequate and least-cost treatment, and it being likely that society would chose to undertake the treatment if the damage occurred.

5.87 It is to be noted that these two methods differ from other "cost" methods such as those based on avoidance costs and restoration costs. A particular feature of the replacement cost and costs of treatment methods is that they aim at estimating the price of a single ecosystem service instead of considering a basket of ecosystem services.

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57 It is to be noted that, as there are no ecosystem services associated with the extraction of non-renewable natural resources (such as mineral and energy resources), the valuation of those resources are not discussed here. See the SEEA Central Framework, chapter V, for details on the valuation of non-renewable resources.

Payments for ecosystem services and trading schemes

5.88 Increasing experience has been gathered in the area of establishing markets for regulating services, in particular carbon sequestration and, to a smaller degree, hydrologic services such as the regulation of water flows (flood mitigation) and control of sedimentation. For carbon, there are a range of markets operating in different parts of the world at different levels of maturity and market turnover. The largest market is the European Union Emissions Trading System, but this market does not include carbon sequestration in ecosystems. Indeed, it is important to distinguish between markets associated with the limited right to emit pollution and markets in ecosystem services themselves, since the design of the market will influence the interpretation of the prices that are generated. In compliance markets, the price of carbon is strongly influenced by the regulatory setting of the market, and prices have fluctuated rapidly in response to changes in the setting.

5.89 Carbon sequestered in ecosystems is mainly traded in voluntary carbon markets, which are rapidly evolving. A scheme in New Zealand permits the trading of credits from forest carbon under a compliance scheme, but so far only small quantities of forest carbon have been traded.

5.90 Further, most market transactions in forest carbon cover the flows associated with sequestering carbon rather than the service of permanent storage of carbon in ecosystems. Recently, however, a number of pilot projects in the domain of the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD) have commenced. These projects sell carbon credits from reduced carbon emissions to the atmosphere generated by activities aimed at reducing deforestation and/or degradation and hence maintaining the carbon stored in an ecosystem. Payments are made, in the case of UN-REDD, for reducing emissions, as compared with a baseline case of business-as-usual emission rates, that is, with no UN-REDD project in place.

5.91 The nature of the market for both the sequestration and storage of carbon in ecosystems reflects how carbon services are defined for SEEA Experimental Ecosystem Accounting (see chap. III). With respect to establishing a price for carbon, a first estimate may be made based on the prices in voluntary markets. Potentially, when compliance carbon markets mature and further allow the inclusion of carbon storage and/or sequestration in ecosystems, new (generally higher) prices raised in these markets may be used to value carbon.

5.92 The valuation of ecosystem services may also be considered through the analysis of markets in biodiversity, providing that connections can be made between the market values of biodiversity and the ecosystem services of interest. Market-conforming biodiversity mitigation mechanisms include mitigation banking of biodiversity credits, programmes that channel development impact fees and offset policies. A limited number of biodiversity markets have been set up that demonstrate the basic characteristics of a market: (a) the presence of buyers and sellers; (b) a traded unit, reflecting biodiversity; (c) a market clearing mechanism through which a price is established; and (d) an institutional setting regulating the market and ensuring compliance. The units traded in these markets are commonly credits related to species or to acreage of habitat conserved.

5.93 Examples of emerging biodiversity markets include (a) conservation auctions in Victoria, Australia; (b) BioBanking in New South Wales, Australia; and (c) conservation banking in the United States of America. These schemes allow a surrogate market price to be established for the biodiversity units traded in such markets; but it needs to be kept in mind that the prices of the units strongly depend on the local ecological and institutional setting and cannot easily be converted to the values of biodiversity in other places.

5.94 Overall, it may be that markets and trading schemes provide a good basis for estimating prices for certain ecosystem services. However, care must be exercised when attempting to understand the extent to which the institutional setting for these markets ensures that the prices conform to assumptions regarding market prices. In particular, it is important that the prices generated from the markets and trading schemes be incentive-compatible. An observation in this regard is that prices from voluntary markets and prices due to regulation may not equate to measures of societal willingness to pay.

Revealed and stated preference methods

5.95 Studies using revealed preference and stated preference methods for non-market ecosystem services have been well developed in the environmental economics literature. Revealed preference methods determine the value of an ecosystem service based on observations of related market goods. These methods include production function, hedonic pricing, averting behaviour methods and travel cost methods, as described below. Rather than rely on behaviour exhibited in existing markets, stated preference methods depend on questionnaires or experiments to analyse individual preferences. Contingent valuation and choice experiments are the two main types of stated preference methods. A short overview of these valuation approaches is also presented below.

5.96 Many of these valuation methods have been used to estimate changes in consumer surplus resulting from a proposed policy change or the aggregate level of consumer surplus for a given environmental asset. Some caution must therefore be exercised when evaluating these models and their associated values for use in an ecosystem accounting context, for the reasons described in section 5.3.

5.97 All revealed and stated preference methods rely on the construction of some type of demand curve or the use of an existing market with an underlying utility function. Consequently, there exists the potential, with further analysis of the models from an exchange value rather than a welfare economic value perspective, for these approaches to provide data or functions to be applied to estimate exchange values for use in ecosystem accounting.

5.98 *Production function methods* estimate the contribution of ecosystem services to production processes in terms of their contribution to the value of the final product being traded on the market. The general objective of disentangling the contribution of the ecosystem from contributions of other production factors, is analogous to using the resource rent as a proxy for the monetary value of provisioning services. These methods require an understanding of the links between ecosystem services and the relevant market product, for example, the link between the preservation of a wetland, its fish habitat and the catch of fish. Production function methods can also be used to value indirect use values generated by regulating services, such as storm and flood protection services, by disentangling their contribution to the generation of outputs traded in a market.

5.99 *Hedonic pricing methods* analyse how environmental qualities affect the prices that people pay for market products or assets. For example, hedonic pricing can be used to determine the value of local ecosystem services that contribute to the value of a property, as in the case where urban green space increases local house prices. In this case, hedonic pricing involves decomposing sale prices of houses into implicit prices for the characteristics of the house (e.g., number of rooms, size of the lot), local ecosystem services and other factors.

5.100 Hedonic pricing methods may also be used in valuing ecosystem assets, for example, forests, for which there are a range of possible uses, and hence a range of ecosystem services, which each need to be priced. Hedonic valuation in this situation may also reveal option values, for possible alternative uses of an ecosystem asset in the future. The application of hedonic pricing analysis requires a sufficiently large amount of data to permit statistical identification of the relevant characteristics of the land areas, including the availability of ecosystem services.

5.101 *Averting behaviour methods* are indirect approaches to evaluating the willingness of individuals to pay for improved health or to avoid undesirable health consequences. Averting behaviour models are based on the presumption that people will change their behaviour and/or invest money to avoid an undesirable outcome resulting from ecosystem degradation. The incurred expenditures provide an indication of the monetary value of the perceived change in environmental conditions.

5.102 Contrary to the replacement cost valuation method (see above), the averting behaviour method is based on individual preferences. For example, in the presence of water pollution, a household may install a filter on the primary tap in the house to remove or reduce the pollutant. In order for this method to be applicable, it is necessary for households to be fully aware of the impacts exerted on them by environmental changes. However, owing to lack of information, behaviour with only a short-term focus and the complexity of the process of assessment, the averting behaviour method will often underestimate the value of the service. Indeed, people may be unaware of environmental factors or too income-constrained to participate in averting behaviour.

5.103 *Travel cost methods* are often used to value ecosystem services associated with recreational sites. These methods estimate the value of the ecosystem services based on the amounts that consumers may be willing to pay as reflected in the costs of visiting a recreational site (e.g., transport costs, travel time, visiting time). Single-site travel cost models may introduce difficulties in determining the value placed on an ecosystem service or the condition of a service provided at a site, unless the methods are applied over time and the service and/or the condition varies over time. Multi-site models employ a random utility framework which can permit the researcher to determine the value placed on an attribute common across the recreational sites (e.g., how much one would pay for an additional unit of beach width or beach length).

5.104 Generally, as studies using travel cost methods focus on estimating total willingness to pay, the valuations incorporate measurement of some of the consumer surplus generated for visitors to ecosystems. Depending on the method used, it may be possible to derive estimates from these studies consistent with exchange values or to conduct studies designed to estimate exchange values.

5.105 *Stated preference methods* are designed to capture information on people's willingness to pay for ecosystem services without observing an actual payment or transaction. The most important approaches are contingent valuation and choice experiments. Contingent valuation studies typically ask respondents to state the value they attribute to a certain ecosystem asset, ecosystem characteristic or ecosystem service, or the value they place on a project that will preserve that asset, characteristic or service. In choice experiments, respondents are asked to select from a range of available options with varying levels of ecosystem services, and corresponding prices for the associated bundle of services. If designed correctly, this can permit valuation of different ecosystem attributes.

5.106 For each of these stated preference methods, the set-up of the questionnaire is critical; respondents need to be presented with a credible case for a potential payment for an ecosystem service. Econometric procedures can then be used to determine monetary values on the basis of choices or ranks.

5.107 The main advantage of stated preference methods is that, unlike other valuation methods, they can be used to quantify non-use values of an ecosystem in monetary terms.

These methods can also be used to value ecosystem conditions that do not currently exist or ecosystem services that may become available in the future. Contingent valuation estimates are sensitive to the specific framing of the questions designed to elicit estimates of willingness to pay. For example, the sum of the values obtained for the individual components of an ecosystem may be higher than the amount of the stated willingness to pay for the ecosystem as a whole. In addition, contingent valuation measures may overestimate economic values if respondents do not believe that they will actually have to pay the amount they say they would be willing to pay for a service (and are therefore not incorporating their budget constraint). As studies using these methods typically incorporate estimates of consumer surplus, the results should not be used directly to estimate exchange values.

Approaches to modelling exchange values

5.108 A number of the valuation approaches described above (e.g., the travel cost method and the averting behaviour method) can be used to derive a demand curve representing the willingness to pay for particular ecosystem services. Consistent with the discussion on valuation concepts in section 5.3, a possible step in the estimation of exchange values would be the estimation of a supply curve for the same ecosystem service. If this step could be completed, then the intersection of the supply and demand curves would provide an estimated exchange value, from a hypothetical market. It may be possible to use measured quantities of ecosystem service flows to reflect the level of supply.

5.109 An approach has been developed that seeks to create hypothetical markets. The simulated exchange value approach has been proposed by a team of economists from Spain in the specific context of accounting in the forestry sector. The approach aims at measuring the income that would be produced in a hypothetical market where ecosystem services were bought and sold. It involves estimating a demand curve and a supply curve for the ecosystem service in question and then making further assumptions on the price that would be charged by a profit-maximizing resource manager under various market scenarios. The method then takes the hypothetical revenue associated with this transaction (excluding the associated consumer surplus) as a measure of value of the flow of ecosystem services. As the simulated exchange value approach estimates the value of ecosystem services in terms of potential revenue, it can be argued that the basis of this method is more consistent with the inclusion of their value in national accounts alongside monetary transactions.

5.6 Key measurement issues in valuation

5.6.1 Measuring regulating services

5.110 Unlike cultural or provisioning services, the biophysical performance of regulating services, and thereby their economic value, is influenced by the state of other ecosystems in a specific area. For example, the relationship between an area covered with forest and the regulation of downstream flood levels is non-linear: a small reduction of forest cover will not reduce the service to a significant degree but a large reduction in land cover may so reduce the service. Similarly, in a watershed with an initially high forest cover, the different plots have a low marginal value related to flood control, and conversion of a few plots does not lead to increased flood risks downstream. However, when forest cover is further reduced, the impact of one unit of extra deforestation on flood risk will often strongly increase. This is typical for many regulating services. For ecosystem accounting, this means that values of regulating services will normally be variable over time as a function of the state of the ecosystem.

5.111 The value of regulating services will also vary over time as a function of economic development: the greater the number of people living in an area where their economic activity (including consumption) is supported directly or indirectly by a regulating service, the higher the value of the regulating service. In the most extreme case, if no one is living in the area where the potential benefits of the regulating service arise, the exchange value of the service may be zero. To reflect these changes in population and demand, estimates of the value of regulating services need to be updated regularly.

5.6.2 Aggregation

5.112 Ultimately, for some of the purposes of ecosystem accounting, valuation must go beyond the stage of determining appropriate approaches to the estimation of prices and values for individual ecosystem service flows. To integrate monetary estimates of ecosystem services within broader accounting frameworks, it is necessary to undertake aggregation, which must be considered in its different forms: (a) aggregation of the value of different ecosystem services within a single ecosystem; (b) aggregation of the value of ecosystem services across multiple ecosystems; and (c) aggregation of the value of expected ecosystem services flows to obtain an estimate of the value of an ecosystem asset. This section considers each potential aggregation in turn. It is to be noted that, at each level of aggregation, the complexities involved and the assumptions required increase, since the challenges of estimation at the level of an individual ecosystem do not diminish when estimation is undertaken on a larger scale.

Aggregation within a single ecosystem

5.113 Assuming that the valuation of ecosystem services is possible, the logic underpinning the concept of aggregation is akin to that guiding the addition of values of output from an enterprise that produces a range of different outputs. Thus, for a given accounting period, it should be possible to sum the estimated values (price times quantity generated) of the different ecosystem services. This might be used to compare both the values of ecosystem services provided by different ecosystems and values of different ecosystem services within a single ecosystem.

5.114 While simple in concept, this approach assumes that each ecosystem service is independent, that is, the value of each service is net of the added value from interdependent services. In practice, it may be difficult to isolate ecosystem services in terms of their price and quantity. Aggregation of this type should ideally take into consideration cross-ecosystem dependencies. If dependencies between ecosystem services are not taken into account, then the contributions of individual ecosystem services might be double-counted. Resolution of these issues is likely to require a thorough understanding both of the relevant ecosystem processes in physical/scientific terms and of the contributions of ecosystem services to human well-being. Ongoing research into bundling and stacking in ecosystem services measurement may provide guidance in advancing the resolution of this aggregation question.

5.115 Aggregation within an ecosystem will be affected by the consistency in the approaches to valuation of individual ecosystem services. Certainly, where different approaches provide estimates related to different valuation concepts (i.e., exchange value or welfare economic value), it will be difficult to interpret the resulting aggregates. However, even in cases where a consistent valuation concept is applied, the use of different measurement approaches for different ecosystem services may still result in gaps and overlaps in valuation which need to be considered.

5.116 The degree of meaningfulness of the resulting sum of values of different ecosystem services depends on the level of coverage of the measured ecosystem services. In cases where the ecosystem services measured do not provide a relatively complete coverage of the set of ecosystem services, the aggregated value may be of reduced usefulness. An important starting point in this regard is the comprehensive measurement of ecosystem service flows in physical terms.

Aggregation across ecosystems

5.117 Aggregation across ecosystems, for individual or multiple ecosystem services, raises the same issues outlined above. In addition, the challenge of appyling value transfer methods arises to the extent that direct valuation of each ecosystem service in each ecosystem is not possible. In general terms, value transfer involves using information from one ecosystem to estimate values in another, similar ecosystem after adjusting for various characteristics such as size or proximity to population centres. Value transfer is discussed further directly below.

5.118 As the range of ecosystem types and the number of ecosystems and ecosystem services analysed increase, the aggregation issues become more complex. Depending on the analytical questions under investigation, this step in the process of aggregation should be undertaken cautiously. It may be of interest to aggregate the values of a single type of ecosystem service that is generated from a number of different ecosystems (e.g., carbon sequestration services across all ecosystem assets). While this type of aggregation is still likely to require application of the rules appropriate to the service measured (e.g., summary, averaging, prorating) and the use of value transfer methods, the focus on a single ecosystem service nevertheless limits the impact of the issues that also arise in the course of aggregating different types of ecosystem services.

Aggregation aimed at creating values for ecosystem assets

5.119 For certain purposes, it may be relevant to compile measures of the value, in monetary terms, of ecosystem assets. The motivations for and limitations associated with undertaking this compilation are discussed at some length in chapter VI. For the purposes of the present discussion, the starting point in estimating aggregate values of ecosystem assets is the assumption that the expected future flows of each ecosystem service can be valued and then discounted to the current period. This enables a net present value (NPV)-based estimate of ecosystem assets to be derived, following the same accounting logic as is applied in standard asset accounting.

5.120 The measurement of NPV-based estimates of ecosystem assets poses a number of challenges, including:

(a) The need to make assumptions regarding the combination of future ecosystem services flows. In an accounting context, it is most likely preferable to determine this combination based on a continuation of a business-as-usual scenario rather than on any of a range of alternative scenarios that may be envisaged for the use of the ecosystem. (The development of alternative scenarios for analytical purposes is possible as an application of the SEEA Experimental Ecosystem Accounting framework.);

(b) The need to formulate, as part of developing expected estimates, an asset life, that is, the expected period of time over which the ecosystem services are to be delivered. Given the potential for ecosystems to regenerate, implicit in determining an asset life is some perspective on the extent to which the delivery of the current set of ecosystem services is sustainable ((a) and (b) are necessarily related challenges);

(c) As with aggregation within ecosystems, understanding dependencies between ecosystem services and assets and the nature of those dependencies in future periods. Ideally knowledge would exist not only about relationships in the present period but also about how those relationships might change in the future, taking into account the likely non-linearities involved (it is to be noted that relevant knowledge should also be considered under (a) and (b));

(d) Selection of an appropriate discount rate for derivation of NPV estimates. This is not a straightforward choice and, depending on the context, may require consideration of various equity and other issues, including intergenerational equity. The SEEA Central Framework discusses discount rates and concludes that for the purpose of alignment of SEEA values with the SNA, it is necessary to select marginal, private, market-based discount rates in NPV calculations. However, this may be deemed inappropriate for ecosystems as a whole whose value may be considered improperly reflected at the margin.

5.121 Given all of these considerations, careful thought should precede application of standard NPV approaches to the valuation of ecosystem assets. Depending on the analytical and policy requirements, aggregate measures of ecosystem assets may not be needed. It is also to be noted that where there is an intent to integrate values for ecosystem assets with the values of other assets (e.g., produced assets such as buildings and machines, and non-produced assets such as land), care should be taken to ensure that the values of expected flows of ecosystem services and the expected flows of income from produced and other assets can be clearly distinguished. This may be particularly relevant in assessing the value of land as distinct from any associated ecosystem asset.

5.122 One reason for undertaking these valuations is to determine the change in the value of ecosystem assets and hence derive measures of ecosystem degradation in monetary terms. Issues concerning the definition and measurement of ecosystem degradation in monetary terms are discussed at length in chapter VI. It is noted here that measurement of the change in the value of ecosystem assets requires consideration of all of the factors listed above and cannot be related simply to movements in the prices and quantities of ecosystem services between two accounting periods. Under this approach to ecosystem degradation, it is the change in the complete time series of expected ecosystem service flows that is important.

5.6.3 Benefit transfer

5.123 The discussion of valuation for ecosystem accounting is focused on the development of estimates in monetary terms for large regions or countries which may be used for the development, implementation and/or monitoring of public policy. However, in practice most work has focused on the valuation of ecosystems and ecosystem services in smaller, more targeted settings for specific ecosystems or in relation to particular contingencies, for example, the damages caused by oil spills. Consequently, data on the value of ecosystem services are fragmented, covering only specific services over a large area, or multiple services in a more confined area, or changes in the flow of ecosystem services following a specific event. In general, great care must be exercised when extending value estimates for ecosystem services or ecosystem assets to other areas.

5.124 There are three principal approaches to benefit transfer: value transfer, benefit function transfer and "meta-analysis" function transfer. A value transfer utilizes a single estimate of the value of an ecosystem service, or an average of several value estimates from different studies, to estimate the value of an ecosystem service in a different context. Rather than transfer the single estimate of value, a benefit function transfer takes the function estimated from a primary research study in one context and applies it in another context.

5.125 A more comprehensive means of carrying out benefit transfers is to use meta-analysis, which utilizes all existing studies to construct a relationship that reflects changes in the values of ecosystem services as a function of, inter alia, site characteristics, attributes and size of population affected, and the type of statistical method used in the analysis of existing studies. The results of the meta-analysis are then transferred to the new application in a procedure referred to as meta-regression value transfer, which applies a range of values to the new application based on the characteristics embedded in the meta-regression. This approach is well suited to developing estimates for additional sites but may need to be supported by other techniques if it is to provide estimates at larger scales, including at the national level.

5.126 The values provided by ecosystem services are often strongly dependent on the biophysical, economic and institutional context, which makes it difficult to assume that value estimates of specific services apply also in a different context. Furthermore, ecosystems are likely to be highly interdependent. The value of one unit of an ecosystem is therefore likely to be contingent on the existence or proximity of other ecosystem components. In these situations, asset values are known to be interdependent rather than *unique* (as is the case with values revealed on regular markets). Given the likelihood of differences in quality of ecosystem services between ecosystems, a simple value transfer based on average prices is unlikelyto be appropriate and meta-analysis function transfers are likely to be required.

5.127 At the same time, the number of point estimates of value or functions available for transfer is dependent on the type of ecosystem service being considered. For example, while there are many studies of the recreational use of wetlands, there are not as many studies on their value. Also, the fact that different valuation studies are often based on different assumptions and use different methodological constructs leads to differing levels of confidence in the estimates produced. Given the limited data points for certain ecosystem service types, the variability in approaches and the lack of common functional variables across studies, benefit transfer is prone to a high degree of uncertainty, particularly if poorly executed. Therefore, in addition to efforts aimed at improving benefit transfer methods, there must be a focus on increasing the number of observations through additional valuation studies in order to improve the overall quality of the estimates.

5.6.4 Uncertainty in valuation

5.128 Uncertainty can be associated with any of four significant dimensions of ecosystem accounting: (a) physical measurement of ecosystem services and ecosystem assets; (b) valuation of ecosystem services and ecosystem assets; (c) the dynamics of ecosystems and changes in flows of ecosystem services; and (d) future prices and values of ecosystem services:

(a) *Uncertainty related to physical measurement of ecosystem services and ecosystem assets.* It is clear that, given the scarcity of data for many ecosystem services, physical measurement of the flow of ecosystem services, in particular at aggregated levels, is prone to uncertainty. Most countries do not consistently measure flows of ecosystem services at an aggregated (national or even subnational) scale, since usually service flows need to be estimated using point-based observations in combination with spatial data layers and non-spatial statistics. At the same time, it is to be noted that information related to flows of provisioning services is, generally, readily available;

(b) *Uncertainty in the valuation of ecosystem services and ecosystem assets.* This type of uncertainty is associated with determining the monetary value of ecosystem services. For provisioning services, a key consideration is that attributing a resource rent to ecosystems involves a number of assumptions regarding rent generated by other factors of production. For other ecosystem services, it is often difficult both to establish the demand for these services and to determine the supply of these services by ecosystems, in particular at an aggregated scale;

(c) *Uncertainty related to the dynamics of ecosystems and changes in flows of ecosystem services.* Establishing the value of ecosystem assets requires making assumptions regarding the supply of ecosystem services over time, which in turn depends on the dynamics of the ecosystem. Changes in ecosystem assets will often be reflected in a changed capacity to supply ecosystem services. It is now recognized that ecosystem changes are often sudden, involving thresholds at which rapid and sometimes irreversible changes occur in a new ecosystem state. Predicting the threshold level for, and timing of, such changes is a complex undertaking and one that is prone to substantial uncertainty;

(d) *Uncertainty regarding future prices and values of ecosystem services.* Pricing benefits and costs that may accrue in the future is a complex task. The implications for ecosystems of humanity's continuing modification of climate and landscape are uncertain and are likely to both affect and depend on how the future evolves. Uncertainties concerning values are even greater inasmuch as the methods of non-market valuation tend to compound errors in estimation.

5.129 While the best strategies for dealing with the sources of uncertainties will vary by country, as a function of data availability and the relevant services selected for ecosystem accounting, there has been limited experience to date in analysing ecosystem services in both physical and monetary terms at the national level. The approaches to limiting those uncertainties and maximizing the robustness of ecosystem accounting will need to be further developed once more practical experience with ecosystem accounting has been gained and evaluated. The experiences gathered from national-level assessment of ecosystem services supply are highly relevant in this context[58] and it is therefore important that all projects provide clear information on the scope of the ecosystem services that have been valued and the related assumptions and uncertainties.

58 See, for example, UK National Ecosystem Assessment (2011).

Chapter VI

Accounting for ecosystems in monetary terms

6.1 Introduction

6.1 Accounting for ecosystems in monetary terms is an important consideration in ecosystem accounting, since a common objective is to bring together information on ecosystems with measures of economic activity which are usually expressed in monetary terms. One means of bringing this information together is to create presentations that combine measures for ecosystem services and ecosystem assets in physical terms with standard economic measures such as value added, income and employment. As described in chapter VI of the SEEA Central Framework, these combined presentations may take a variety of forms depending on the topic or question of interest. They may be particularly appropriate in cases where, for some accounting entries, valuation in monetary terms is not possible but relevant physical information may still be of use. Section 6.2 below describes relevant measurement issues.

6.2 A second approach to considering ecosystem accounting in monetary terms is to bring together valuations of stocks and flows of ecosystem assets in an ecosystem asset account following the standard asset account structure outlined in the SEEA Central Framework. Although seemingly straightforward, the development of an ecosystem asset account in monetary terms does require the use of some significant measurement assumptions, most prominently, that it is possible to derive the economic value of ecosystem assets as the sum of the discounted value of the future stream of ecosystem services. Section 6.3 discusses the relevant assumptions and approaches, with a particular focus on the measurement of ecosystem degradation in monetary terms.

6.3 A third approach is to use valuations of ecosystem services and ecosystem assets in monetary terms to augment standard national accounts and aggregates. There are a number of incentives for considering such an integration, generally centred around the notion that, in some situations, it is beneficial to provide information on economic and other human activity that occurs outside the market and/or is not recorded in the standard economic measures of production, consumption, income and wealth. Providing this information in a manner that relates directly to the standard economic measures may significantly aid analysis and interpretation. It is therefore usual for work in this area to start with the concepts and structures of the SNA and proceed with efforts to find ways to formulate alternative presentations and aggregates.

6.4 The present chapter introduces possible areas for integration of ecosystem accounting and standard presentations of economic accounts but deliberately refrains from providing specific recommendations, for the following reasons:

(a) There are differing views about the meaningfulness of integrated measures and accounts in light of the assumptions required for valuation in monetary terms and, consequently, about the ability to use integrated measures and accounts for policy purposes;

(b) There are concerns within the official statistics community regarding whether the types of adjustments and extensions to the SNA that are commonly described fall within the purview of official statistics;

(c) There has been no definitive conclusion to the conceptual discussion on integration of ecosystem accounting with the SNA; alternative presentations may be justified depending on the particular environmental situation or the particular question of policy-related interest;

(d) There remains a range of significant measurement challenges.

6.5 Notwithstanding these concerns, SEEA Experimental Ecosystem Accounting would be incomplete without placing in context the considerable effort that has been devoted to conceptualizing adjustments and extensions to the SNA. It is therefore appropriate that the key measurement issues associated with accounting for ecosystems in monetary terms are introduced in the present chapter (see sect. 6.4).

6.6 The discussion on combining ecosystem accounting with standard national accounts is becoming increasingly relevant as countries, both nationally and multinationally, are recognizing the scarcity of some ecosystem services and developing policy instruments to manage that scarcity. Where new property rights are established and new transactions arise, there is an overlap between the aims of adjusting for environmental concerns and including these transactions in the existing framework of the SNA. Thus, the treatment of payments for tradable emissions permits, for example, is an important issue for the SNA, as there are transactions, assets and liabilities that must be recorded. To the extent that ecosystem services are "internalized" in the SNA, there is a need to understand the changing measurement boundary.

6.2 Combined presentations for ecosystem accounting

6.2.1 Introduction

6.7 Combined presentations offer a means of assessing changes in stocks and flows of ecosystems in the context of standard measures of economic activity without having to undertake the step of valuation of ecosystem services and ecosystem assets in monetary terms. An example of a combined presentation is one where expenditures on environmental protection for a specific ecosystem asset are compared with changes in ecosystem condition in physical terms for the same asset.

6.8 In combined presentations for ecosystem accounting, the most significant area of interest is likely to cover linking physical measures of ecosystems with standard economic transactions that are considered to be related to the environment. Chapter IV of the SEEA Central Framework covers the recording of the relevant transactions by: (a) describing the compilation of the environmental protection expenditure account (EPEA) and statistics on the environmental goods and services sector (EGSS); (b) defining environmental taxes and environmental subsidies and similar transfers; and (c) outlining the general treatment of payments for access to or use of natural resources and the environment.

6.9 All of the definitions and treatments of these transactions as outlined in the SEEA Central Framework apply equivalently in SEEA Experimental Ecosystem Accounting. This reflects that the treatments in the Central Framework are elaborations of the treatments of the transactions from a standard SNA perspective and therefore there is no requirement to adopt alternative treatments of the same transactions for ecosystem accounting.

6.10 At the same time, since ecosystem accounting represents a different perspective on environmental accounting more generally, the present section examines particular areas of the general treatment of transactions related to the environment—namely, information on environmental activity; linking ecosystems and ecosystem services to economic activity; and treatment of payments for ecosystem services—that are likely to be most relevant when assessing ecosystems.

6.2.2 Information on environmental activities

6.11 As defined in the SEEA Central Framework, environmental activities are either environmental protection activities or resource management activities. These are economic activities within the production boundary of the SNA that have as their primary purpose either the preservation, reduction and elimination of pollution and other forms of degradation or the presentation and maintenance of the stock of natural resources. Traditionally, it is expenditure on these types of activities that has been a focus of accounting. Increasingly, however, there is interest in also measuring the production of environmental goods and services, that is, goods and sevices produced for the purpose of environmental protection or resource management and relevant adapted goods. (For details, see the SEEA Central Framework, chap. IV).

6.12 From the perspective of ecosystem accounting, there may be particular interest in combining information on ecosystem services and ecosystem assets with information on expenditure on environmental protection or resource management. If the information was organized on the same spatial scales, this would facilitate monitoring the effect of expenditures on changes in ecosystems. Thus, information might be organized by type of LCEU with, for example, information on expenditure to restore coastal wetlands being combined with information on associated changes in ecosystem condition.[59]

6.13 At a national level, it may be useful to focus on the development of expenditure accounts for subsets of environmental protection and resource management activity that are particularly directed towards the maintenance and restoration of ecosystems. The compilation of targeted statistics on the production of ecosystem-related environmental goods and services, using the framework of statistics on EGSS, may also be of interest. These statistics would, for example, provide information on the share of overall value added contributed to the economy through the production of goods and services that are designed specifically for the protection or management of ecosystems.

6.2.3 Linking ecosystem assets and ecosystem services to economic activity

6.14 Although the focus of ecosystem accounting is often on the additional services provided by ecosystems, there is also interest in understanding the significance of the relationship between ecosystems and standard measures of economic activity, such as gross domestic product (GDP). For example, it may be of interest to understand the contribution of ecosystem services to agricultural production.

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59 It may be difficult to allocate survey data collected at national level to specific ecosystem assets and thus necessary to consider alternative approaches to collecting data on site-specific expenditures, for example, through administrative sources.

6.15 One useful approach entails aligning the spatial coverage of ecosystem data and measures of economic activity, possibly using information on land use or landownership, so that flows of ecosystem services and changes in ecosystem assets can be related directly to measures of output, employment and value added in the same spatial areas. (It is to be noted that the most appropriate spatial boundaries will vary for different ecosystem services, which may need to be taken into account in interpreting any detailed spatial information.) Additional benefit would be gained by integrating estimates of population at aligned geographical levels. Increasingly, socioeconomic data are being organized at finer levels of detail using geographic information systems (GIS) and related techniques. Nonetheless, a balance will need to be struck between the potential for disaggregating economic data to finer spatial levels and the meaningfulness of aggregating ecosystem data to broader spatial levels.

6.16 It should be accepted that the allocation of economic activity to small spatial areas can be conceptually difficult and may require the use of various indicators. For example, the ideal spatial allocation of transport activity is not obvious. Therefore, it may be most useful to commence with identification of measures of economic activity for those industries and activities, for example, agriculture, forestry, fishing and tourism, where a clear link can be established between an ecosystem and the location of production. This information may be of particular use in considering the allocation of ecosystem degradation to economic units.

6.17 Where links between economic units and particular ecosystems can be established, it is also possible to consider integrating information on a range of other transactions that may occur in connection with the economic activity. For example, payments of certain environmental taxes, of rent on natural resources and of environmental subsidies and similar transfers may be combined with standard economic indicators and indicators of ecosystem services and assets to provide a more complete picture of the relationships between a given ecosystem and the economy.

6.2.4 Treatment of payments for ecosystem services

6.18 The specific case of payments for ecosystem services (PES) illustrates the link between ecosystems and economic transactions. PES are incentives offered to landowners (often farmers) in exchange for managing their land so as to provide some type of ecosystem service. The payments reflect "a transparent system for the additional provision of environmental services through conditional payments to voluntary providers" (Tacconi, 2012). PES relate to ecosystem services that contribute to non-SNA benefits, it being assumed that those ecosystem services that contribute to SNA benefits are already captured in current transactions.

6.19 Since PES are monetary transactions in scope of the SNA, their accounting treatment should follow the SNA. To a large extent, this will depend on the nature of the scheme that is in operation. Notwithstanding the use of the term "payments for ecosystems services", in fact no payments are made to the ecosystem generating the relevant ecosystem services. Instead, payment is made to an economic unit which, in return, undertakes various remedial actions or changes the patterns of use of the ecosystem (this might potentially entail not undertaking certain economic activity), with the objective of maintaining or increasing the supply of ecosystem services.

6.20 Given the conceptualization of ecosystem services that has been developed in SEEA Experimental Ecosystem Accounting, it is reasonable to conclude that any payments reflect the "marketization" of flows that would otherwise be considered outside the scope of the SNA production boundary. The corollary is that where there is no transaction or payment, then the ecosystem services are not within scope of the SNA. It is to be noted that the economic unit may also be required to incur current and capital expenditures which are likely to be already recorded, following SNA accounting practices.

6.21 The approach is analogous to the treatment of the provision and consumption of services within the home. Following the SNA, childcare provided by parents at home is considered outside the production boundary, but in the case where childcare services are provided by economic units in return for money (or equivalent to money), the activity is considered to be inside the production boundary.

6.22 As noted, in a combined presentation, the organization of information based on spatial areas is relevant. For given ecosystems, a combined presentation may show flows of PES together with information on the flows of ecosystem services and measures of ecosystem assets. In addition, where payments are made for the undertaking of ecosystem maintenance or restoration activity, it would be relevant to link this information with information on expenditure on these activities (see the previous subsection) so as to ensure consistent accounting of the relevant transactions.

6.3 Accounting for ecosystem assets in monetary terms

6.3.1 Introduction

6.23 The measurement of changes in ecosystem assets, and in particular ecosystem degradation, is an important component of environmental-economic accounting. Using the framework for asset accounts as described in chapter V of the SEEA Central Framework, the present section presents the possible structure of an ecosystem asset account in monetary terms.

6.24 Underpinning the development of an asset account is the application of the standard asset accounting model, which is also applied to produced assets. In short, the application of this model requires that the values of ecosystem service flows be considered analogous to those of income flows. The fact that the set of ecosystem service flows described in SEEA Experimental Ecosystem Accounting contribute to both SNA and non-SNA benefits implies that the production boundary, and the associated boundaries of consumption and income, are broader in SEEA Experimental Ecosystem Accounting compared with the SEEA Central Framework and the SNA. The extension of the income boundary ensures that there is alignment between the characterization of the asset and production boundaries.

6.25 The application of the standard asset accounting model to ecosystem assets raises numerous concerns that must be considered before such an exercise is undertaken. A particular concern is related to comparison and aggregation across various types of assets (e.g., comparing values of produced assets, environmental assets and human capital). When the values of ecosystem assets are estimated in monetary terms, it becomes possible to compare and aggregate these values across asset types because the same measurement unit (money) is used. However, comparisons between the various asset values may lead to misleading conclusions regarding sustainability, since it may be implied that the various asset types, including ecosystem assets, can be readily substituted for each other without leading to a loss in the overall value of assets.

6.26 In the present section, the introduction of a possible structure of an ecosystem asset account in monetary terms is followed by a discussion of the valuation of ecosystem degradation, which has been a significant focus of work over many years. Since the discussion, whose key elements are summarized, builds on the discussion of ecosystem degradation in physical terms in chapter IV, readers are encouraged to review that material before considering valuation issues. Overall, given the significant conceptual and measurement challenges involved in developing ecosystem asset accounts, this section is intended only to introduce the possibility of developing such accounts; it does not provide advice or recommendations concerning their compilation.

6.3.2 The structure of ecosystem asset accounts

6.27 The standard asset accounting model permits the development of estimates of the total value of an ecosystem asset in monetary terms. In conceptual terms, the value of an ecosystem asset may be considered to be equal to the discounted value of expected ecosystem service flows. Those values provide the opening and closing estimates of ecosystem assets in monetary terms and can be presented in the form of an asset account, following the structure described in the SEEA Central Framework.

6.28 The basic structure of an ecosystem asset account is shown in table 6.1. Since the estimates are compiled in monetary terms, estimates for different ecosystem assets can, in theory, be summed to provide higher-level aggregates. Given the potential for aggregation, it may be most practical to consider developing asset accounts for particular LCEUs and then aggregating to the EAU level. In large part, however, the determination of the level of estimation will depend on the approaches to the estimation of ecosystem service flows in physical and monetary terms that are adopted. The information might also be presented in combination with information in physical terms.

Table 6.1
Stylized ecosystem asset account entries

	EAU or LCEU
Opening stock of ecosystem assets	
Additions to stock	
Regeneration—natural (net of normal natural losses)	
Regeneration—through human activity	
Reclassifications	
Total additions to stock	
Reductions in stock	
Reductions due to extraction and harvest of resources	
Reductions due to ongoing human activity	
Catastrophic losses due to human activity	
Catastrophic losses due to natural events	
Reclassifications	
Total reductions in stock	
Revaluations	
Closing stock of ecosystem assets	

6.29 Ecosystem degradation is not shown explicitly in the asset account, as it represents the differences between various additions and reductions in ecosystem assets, specifically those related to reductions due to extraction and harvest,[60] to ongoing human activity and

60 It is to be noted that in the case of renewable natural resources (e.g., timber resources), reductions due to extraction and harvest will not usually equate to depletion of those resources, as it is necessary to also account for regeneration and growth of the resources in the estimation of depletion. See the SEEA Central Framework, section 5.4.

to regeneration. Reductions due to ongoing human activity relate to the impacts on ecosystem assets of pollution, emissions, land conversions and other examples of use that are not considered to come under the rubric of extraction of resources. As explained in chapter IV, ecosystem degradation may be considered from a range of perspectives, especially in relation to the accounting treatment of ecosystem conversions. Further discussion on the measurement of ecosystem degradation in monetary terms is presented directly below.

6.30 Ecosystem degradation is only one source of the change in value of the ecosystem over an accounting period. A complete ecosystem asset account also requires consideration of changes in an ecosystem over an accounting period due to

- Major regeneration through ecosystem enhancement
- Losses attributable to significant natural causes, for example, floods or fires
- Reclassifications
- Revaluations

6.31 Major restoration of ecosystems during an accounting period should be recorded separately as an addition to ecosystem assets. This may occur, for example, when major replanting of native species in deforested areas is undertaken. Major restorations of degraded ecosystems should be considered distinctly from relatively continuous patterns of replanting which may be undertaken as part of forestry operations. Finally, major restorations should not be considered an "offset" to reductions in ecosystem assets due to harvesting of timber and other resources in other ecosystem assets, since the impacts on the flows of ecosystem services from different ecosystem assets are not likely to be directly comparable.

6.32 The accounting entry for major restorations of ecosystems relates to a standard national accounts entry for expenditures on land improvements. Expenditures on such restorations constitute a type of gross fixed capital formation and are included in the standard accounts on the basis of the costs of undertaking the enhancements. In a set of augmented national accounts, care should be taken to appropriately integrate these flows of capital formation with changes in the value of the related ecosystems.

6.3.3 Measuring ecosystem degradation in monetary terms

Valuing ecosystem degradation using expected ecosystem service flows

6.33 Since an aggregate value for expected ecosystem service flows can be derived in monetary terms, ecosystem degradation is measured most straightforwardly as the change in value of expected ecosystem service flows over an accounting period. However, in the case of ecosystem conversions,[61] since there is a change in the basket of ecosystem services, the change in value of expected flows will also incorporate the effects of changes in the types of ecosystem services that are expected to be generated. Depending on the purpose of analysis, it may or may not be reasonable to incorporate these effects in measures of ecosystem degradation.

Restoration cost

6.34 Reductions in ecosystem condition represent one aspect of ecosystem degradation. If ecosystem degradation is considered to relate only to reductions in ecosystem condition, then the focus is on the ecosystem asset as a whole. In this case, ecosystem degradation is conceptualized as an aggregate rather than in terms of separable ecosystem service flows. The most

61 Ecosystem conversions refer to cases where the characteristics of a particular spatial area change significantly; for example, a forest area may undergo a conversion to agricultural land.

common approach to the valuation of ecosystem degradation in this situation is to estimate the restoration cost—that is, the estimated expenditure required to return the ecosystem asset to the condition that existed at the beginning of the accounting period.

6.35 Use of a restoration cost approach is associated with a range of contentions, for example, that the implicit price does not reflect a market price, that it is unclear whether the ecosystem should or could be restored to a previous condition, and that the use of an aggregated approach is not conducive to a full allocation of costs to relevant economic units.

6.36 At the same time, this direct approach to the estimation of a possible value of ecosystem degradation resembles the approach commonly used in the estimation of the value of public goods in the national accounts. Further, even if they are not used to value degradation, estimates of restoration cost may still be of interest in their own right.

Damage- and cost-based values of ecosystem degradation

6.37 Historically, the discussion on the measurement of ecosystem degradation in monetary terms has revolved around whether the matter should be approached from the perspective of "how much damage is caused by ecosystem degradation" associated with so-called damage-based estimates; or from the perspective of "how much would it cost to avoid ecosystem degradation" (entailing cost-based estimates). There was no expectation that estimates based on the different perspectives should align, although the extent of ecosystem degradation in physical terms was assumed to be the same in both cases. The differences and the relevant accounting implications are described in detail in chapters 9 and 10 of the Handbook of national accounting: integrated environmental and economic accounting 2003 (SEEA-2003) (United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development and World Bank (2003)).

6.38 Consideration of ecosystem degradation in the context of ecosystem services clarifies the scope of damage- and cost-based perspectives to a significant degree. Thus, damage-based assessments should focus on the value of the reduction in the context of the capacity to generate ecosystem services, and cost-based assessments should focus on the cost of avoiding or modifying the human activity that is causing the ecosystem degradation (avoidance costs). These two values may be quite different, although both may be useful in respect of informing policy options.

6.39 Damage-based assessments are likely to include changes in the value of other assets (e.g., buildings) that may be due to a degraded environment. In theory, these declines in value should already be accounted for in the standard SNA asset accounts as either consumption of fixed capital or other changes in volume. In practice, ensuring that the extent of damages is appropriately attributed to assets so that they are recorded only once is likely to involve a complex accounting exercise. It is necessary to consider (a) whether the changes in the ecosystem are normal and long-lasting, (b) the linkages to related effects, such as productivity and human health, which may or may not be captured in the SNA and (c) the relationship between the value of an ecosystem service and the value of the benefits to which it contributes. Overall, integration of damage-based measures of ecosystem degradation within standard national accounting requires a careful articulation.

Allocation of ecosystem degradation to economic units

6.40 Whatever the approach taken to the measurement of ecosystem degradation, understanding the relationship between ecosystem degradation and specific economic units—enterprises, households and governments—may be of significant value. In this regard, a choice must be made regarding whether the measures of ecosystem degradation in monetary terms are to be allocated to economic units in terms of the ecosystem degradation they cause through their economic and human activity (activity-based allocation) or of the costs they incur (in terms of lost income) as a result of degradation (receiver-based allocation).

6.41 Allocation of ecosystem degradation to economic units on a receiver basis requires assumptions concerning the relationship between economic units and their use of flows of ecosystem services. Allocation to economic units on an activity basis will require assumptions about the relationship between the causes of degradation and economic units. There may be difficulties associated with these allocations since there will not be a neat spatial relationship among the location of an ecosystem asset, the location of the economic units that cause the degradation, and the location of the users of the ecosystem services. Further, it may be necessary to understand and account for differences stemming from the fact that there will be a difference between the time at which ecosystem degradation occurs and the time at which the impacts of the degradation are felt by the various economic units.

6.4 Integration of ecosystem accounts and economic accounts in monetary terms

6.4.1 Introduction

6.42 The present section introduces three means through which ecosystem accounting information may be used to augment the economic accounts of the SNA:

(a) The compilation of balance sheets that compare the values of ecosystem assets with values of produced assets, financial assets (and liabilities) and other economic assets. Considered in this regard are also approaches described in the literature as types of wealth accounting;

(b) The compilation of a sequence of economic accounts, taking into account ecosystem services and other ecosystem flows, especially ecosystem degradation;

(c) The derivation of aggregate measures of economic activity, such as national income and saving, which are adjusted for ecosystem degradation.

6.43 The extent to which estimates of ecosystem services and ecosystem degradation and related measures can be used to augment standard economic accounts depends on the underlying approach taken to the conceptualization of ecosystem assets and ecosystem services. Where the value of ecosystem assets is conceived as being directly related to expected ecosystem service flows, there is a potential for developing integrated sequences of accounts, degradation-adjusted measures and balance sheets. Where this direct connection is not assumed, such augmented accounts cannot be compiled.

6.44 It must be recognized that the augmentation of standard economic accounts does not imply that there is a simple means of extending or adding to economic accounts using information from ecosystem accounting. Rather, there are many entries in the standard accounts that must be reconsidered in the light of efforts to highlight ecosystem accounting flows and care must be exercised to ensure that, where relevant, an appropriate partitioning of accounting entries takes place so that double-counting may be avoided.

6.45 The present section focuses on what might be achievable but deliberately refrains from providing recommendations, for the reasons specified in the introduction, namely: differing views on the meaningfulness of augmented accounts, concerns about the link to official statistics, the size of the measurement challenges and the fact that the conceptual debate continues among accountants on how any form of augmentation should be carried out.

6.46 A further general concern from an accounting perspective is the extent to which the estimates used to populate accounting frameworks are based on directly observed data or are outputs from a modelling process. Generally, fine distinctions cannot be made, since all compilations of national statistics require assumptions of various kinds to enable aggregation of detailed observations. At issue is the robustness of the assumptions and the quality of the modelling, which will vary from case to case.

6.47 While there are a number of concerns at the technical and interpretative levels, it is important that work undertaken to augment the standard national accounts still be placed in the correct context, so that those working in this area or those seeking to understand the work in this area have a basis for their deliberations.

6.48 Work on adjusting or extending SNA income accounts and balance sheets must be considered within the context of the objectives, concepts and measurement challenges outlined in chapters I to V of this publication. Three considerations in particular must be highlighted: adjustment requires assessment of ecosystems in physical terms; adjustment or extension requires the use of valuation techniques to enable derivation of estimates in monetary terms; and adjustment requires aggregated measures of ecosystem services and ecosystem assets.

6.4.2 Balance sheets and wealth accounting

6.49 Measures of well-being and progress are often considered in the context of sustaining a broad stock of assets, capital or wealth. In broad terms, well-being is said to be sustainable if the stock of assets is non-declining over time. Various models can be found in the literature that include economic, environmental, social and human capital. In some cases, the different types of assets may be aggregated in monetary terms or weighted together to form composite indexes.

6.50 Broadly, there are three approaches that have been developed to estimate the stock of assets in monetary terms. The first entails using the general balance-sheet framework of the SNA and extending coverage to incorporate the value of those assets that are not considered economic assets in the SNA. The approach to the valuation of ecosystem assets using exchange values, as described in chapter V, is consistent with this approach.

6.51 The second approach consists in modelling a total value of assets (economic, environmental and social), for example, using the net present value of future consumption, and then decomposing this total value into various asset types. This is the essence of the approach referred to as comprehensive wealth accounting or genuine savings.[62]

6.52 The third approach entails estimating shadow prices for each asset type, including ecosystem assets. As explained in chapter V, in theory, the shadow price incorporates the effects of externalities that are not represented in market prices. This approach is referred to as inclusive wealth accounting.[63] Both the second and third approaches require the use of economic models but may be differentiated by their individual assumptions concerning

62 See, for example, *The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium* (World Bank, 2011).

63 See, for example, United Nations University International Human Dimensions Programme on Global Environmental Change (UNU-IHDP) and United Nations Environment Programme (UNEP) (2012).

sustainability. Further, in practice, the asset boundaries of these different approaches may not be fully aligned, although all three approaches do incorporate ecosystem assets.

6.53 A general concern regarding the extensions made to the balance sheets is that the presentation of the values of different assets side by side, may easily be interpreted as implying that all of the assets are substitutable. Indeed, in some cases, the underlying assumption that the sustainability of well-being requires maintenance of only the total value of the stock may suggest that the mix of assets in the balance sheet is not a significant consideration. The contrasting view is that there are certain assets, particularly environmental ones, that may be essential and not substitutable. This view underlies the notion of critical natural capital.

6.54 In theory, estimates of shadow prices should take into account the extent of the developing shortages in the availability of certain "critical" resources, with the shadow prices rising significantly and the relative value of these assets being very high.

6.55 In practice, there are significant measurement challenges associated with extending the asset boundary to encompass a broad range of assets not included in the SNA and discussions are ongoing on the appropriate conceptual basis for making these extensions.

6.56 The only extensions to the SNA balance sheet that are considered by SEEA Experimental Ecosystem Accounting relate to ecosystem assets valued using the concept of exchange values. However, while the inclusion of values of ecosystem assets does extend the SNA asset boundary, the extension is not a neat one and the values of many ecosystem assets are already partially reflected in the value of economic assets recorded in SNA-based balance sheets. Described below are the boundary issues that should be taken into account.

6.57 It is to be noted that other balance sheet and wealth accounting approaches should also consider these issues, since the value of economic assets that is used in those approaches is usually taken directly from the SNA-based data sets. Hence, there is a potential for double-counting of asset values if the conceptual overlaps described here are not addressed.

6.58 *Treatment of biological resources.* Following the SEEA, all natural and cultivated biological resources (including timber, fish, livestock and plantations) are considered within scope of ecosystem assets. Thus, in aggregating measures of economic and ecosystem assets, care should be taken to avoid double-counting since values for these resources are already recorded following the SNA. Care should also be exercised in considering the scope of cultivated biological resources that are intensively managed (e.g., intensive livestock and horticulture systems) to ensure that the relevant assets are recorded once only.

6.59 *Treatment of mineral and energy resources.* While they are defined in the SEEA Central Framework, these natural resources are not considered part of ecosystem assets, since the benefits they provide are not the result of ecosystem processes. Not only will these resources need to be added to ecosystem assets to enable the derivation of a broader notion of environmental assets, but they should also be included in the category of economic assets, consistent with the scope outlined in the SNA.

6.60 Special consideration may be needed for peat resources which may be used as a form of fossil fuel (and are a part of mineral and energy resources) but also constitute a widely distributed type of soil. In particular, peat soils contain a very significant store of carbon in many different ecosystems. Care should be taken to avoid double-counting of peat soils.

6.61 *Treatment of energy from renewable sources.* Renewable sources of energy (such as wind and solar sources) cannot be exhausted in a manner akin to that in which fossil energy resources are exhausted and, unlike biological resources, neither are they regenerated. Thus, in an accounting sense, there is no physical stock of renewable sources of energy which can be used up or sold.

6.62 At the same time, consistent with the proposals in the SEEA Central Framework, the economic value associated with the ongoing capture of energy from these sources is considered to be embedded in the produced assets used to capture the energy and the associated land and water. The values of produced assets and associated land and water should be included in measures of economic assets, consistent with the asset boundary of the SNA, with no additional valuation in relation to these flows being required.

6.63 *Treatment of water resources (excluding marine).* Depending on the nature of the stock of water in a country, some deep subsoil water might be considered not to be a part of ecosystem operation and hence would lie outside the boundary of ecosystem assets. In that case, additional valuation may be required.

6.64 *Treatment of marine areas.* In both the SNA and the SEEA Central Framework, the stock of water in marine areas is not valued. This is because it is considered that the stock of water is too large to be meaningful for analytical purposes. In SEEA Experimental Ecosystem Accounting, the value of marine environments is captured as part of the various ecosystem services they generate and the volume of water is not a measurement target per se.

6.65 Special consideration may be required with regard to the value of aquatic resources outside a country's exclusive economic zone (EEZ). Following the asset boundary of the SNA and the SEEA Central Framework, some of these resources may be included in the scope of economic assets in circumstances where exploitation control has been established and access rights are defined through international agreements. Within the perspective of SEEA Experimental Ecosystem Accounting, no specific guidance is provided on the precise geographical scope that should be determined as regards marine areas. Thus, care should be taken to reconcile the scope of aquatic resources captured in measures of economic assets with the scope used in the measurement of ecosystem assets. The treatment of migrating and straddling fish stocks may be of particular interest in this regard.

6.66 *Treatment of land.* In some cases, the value of land as recorded in the SNA will provide a useful comparison point with respect to the value of ecosystem assets. Thus, for example, it would be envisaged that, following the SNA, the value of agricultural land provided would incorporate many ecosystem services, at least with regard to those ecosystem services contributing to benefits within the scope of the SNA production boundary. However, there are a number of specific boundary issues that should be considered:

(a) SNA land values will not capture the value of all ecosystem services. However, they may include some effects of, for example, protection from flooding or access to clean water, that are beyond the coverage of values related to agricultural and other production;

(b) SNA land values will incorporate, perhaps to a significant extent, the effect of the location of the land. This location value does not, however, reflect a type of ecosystem service. At the same time, the location of an ecosystem is likely to play a role in the relative demand for certain ecosystem services (e.g., national parks nearer to urban areas will attract more visitors) and will therefore impact on the overall valuation of those services. Consequently, it may not be possible to neatly distinguish the links between land values and values of ecosystem assets;

(c) It may not be possible for some areas of land, perhaps of high ecological significance, to be traded (e.g., national parks). If so, they would not be included in the scope of the SNA asset boundary, since no observable market exists and no stream of economic benefits can be expected. These areas are in scope of the SEEA Central Framework asset boundary in physical terms and, in the context of ecosystem assets, values should be included reflecting the range of non-SNA benefits derived from these areas of land;

(d) Conceptually, urban and built-up areas are a type of ecosystem. Consequently, these areas are within scope of ecosystem accounting and may be of interest for particular purposes (e.g., analysis of the role of public "green spaces" in cities). It is also to be noted that urban populations use significant quantities of ecosystem services, both directly and indirectly. While urban ecosystems may be of interest, often they may not be considered a focus of ecosystem accounting. Hence, care should be taken to ensure that the geographical boundaries being applied in the measurement of ecosystem assets enable appropriate coverage of economic and ecosystem assets in urban areas.

6.67 Since the measurement of ecosystem assets is undertaken starting from a spatial perspective, ideally, adjustments aimed at aligning the measurement boundaries between ecosystem assets and economic assets should also be undertaken spatially, particularly when it is determined that the value of the ecosystem does not lie in the sum of its components but rather in terms of how all of the components function within a given area. The best approach to aggregation may be to determine the spatial scope of ecosystem assets, estimate the value of economic assets in that area and then add on the values relevant to ecosystem services that are not already captured. However, this approach may be difficult to apply in practice, especially if attempting to allocate estimates of national wealth to the institutional sector level.

6.4.3 Sequence of accounts

6.68 A sequence of accounts presents the relationships between all stocks and flows recorded in an accounting system and embodies the relationships within the accounting framework. The starting point for the SEEA sequence of accounts is the standard sequence of accounts presented in the 2008 SNA. The sequence presents accounts for production, the distribution and use of income, capital and financial transactions and balance sheets. While a sequence of accounts may be developed for a country as a whole with flows to and from the rest of the world, a full sequence of accounts also records entries between all of the institutional sectors within an economy, that is, corporations, general government, households and non-profit institutions serving households (NPISH).

6.69 The additional feature of the sequence of accounts described in the SEEA Central Framework, as compared with that of the SNA, is the incorporation of entries for depletion in the various accounts. This addition is described in detail in chapter VI of the SEEA Central Framework. Overall, the sequence of accounts shows very little variation from the standard SNA sequence of accounts.

6.70 In ecosystem accounting, the structure of a sequence of accounts is more difficult to determine because of the distinctive nature of ecosystem degradation in accounting terms, as discussed in the previous section and in chapter IV. Over the past 20 years, a range of alternative accounting proposals have been made.

6.71 The most significant considerations in determining the structure of a sequence of accounts for ecosystem accounting is whether ecosystems are regarded as constituting a separate quasi-institutional sector, alongside corporations, general government, households and NPISH, or whether ecosystem assets are part of the broader stock of assets used by the various institutional sectors, which would eliminate the need for an additional, quasi-sector. Annex A6 describes in greater detail the possible models for a sequence of accounts for ecosystem accounting.

6.4.4 Adjusted income aggregates

6.72 It has long been recognized that GDP and other income measures within the national accounts framework should not be considered measures of welfare or well-being. The 2008 SNA outlines a number qualifications to GDP in this regard, including the scope of consumption, issues of income distribution, the impact of external events (e.g., health epidemics and extreme weather), externalities of production, and various non-economic aspects of welfare, such as life satisfaction. In the context of environmental-economic accounting, there is no intention of accounting for all of these types of factors; hence, any adjusted income aggregates discussed in the SEEA should not be interpreted as providing a broad measure of welfare.

6.73 Notwithstanding the potential limitations, there has been much investigation into income measures that are adjusted for what are generically referred to here as "environmental costs". If these costs are limited to adjustments to income for the costs of depletion of natural resources, then the SEEA Central Framework provides the appropriate accounting for derivation of depletion-adjusted aggregates (see chapter VI of the SEEA Central Framework).

6.74 Beyond measures that adjust for the environmental costs of depletion, there is interest in measures that adjust for the broader costs of ecosystem degradation. While these measures are often referred to as representing "green GDP", this term has also been applied to many other concepts of and approaches to adjusted income measures and is increasingly used, in a different context, to refer to that part of the conventionally measured economy that is considered environmentally related. Thus, indicators to which the label green GDP is affixed do not necessarily relate to a common single concept.

6.75 The measurement of ecosystem degradation in monetary terms provides one means by which income aggregates within the SNA may be adjusted for the costs of degradation. For the purpose of retaining accounting consistency, the income measures themselves should be expanded to incorporate the generation and use of ecosystem services that are not captured within the standard SNA production boundary. A measure of ecosystem degradation may be deducted from this broader income measure to enable degradation-adjusted aggregates to be derived.

6.76 While implementation of this basic approach is theoretically possible, the potential for devising alternative attributions of ecosystem degradation to different economic units and the significant underlying measurement challenges and assumptions explain why no specific adjusted income measure is proposed or recommended in SEEA Experimental Ecosystem Accounting.

6.77 Aside from the challenges already noted in this chapter, adjusted income aggregates suffer (as do all of the measures and aggregates in monetary terms) from the difficulty that the values of the environmental variables cannot generally be determined in a full open-market context. Consequently, the valuations are, at best, estimates of prices at partial equilibria. Extended modelling, in which attempts are made to estimate what GDP (and other income measures) would be if alternative environmental constraints were in existence, is possible. So-called greened economy modelling, for example, derives a measure of income for an alternative state of the economy instead of deriving an alternative measure of income for the existing economy. While there are no specific conceptual accounting issues associated with the adoption of this approach, the fact that it is based on the modelling of alternative scenarios places it outside the scope of the SEEA.

Annex A6

Possible models for a sequence of accounts for ecosystem accounting

A6.1 Proceeding from the brief introduction to the sequence of accounts contained in section 6.4.3, the present annex presents a series of possible models that could be used to incorporate entries related to ecosystem services and changes in ecosystem assets into the standard SNA sequence of accounts.

A6.2 Table A6.1 presents simplified versions of two models (A and B). In the example, presented for a farm, a single ecosystem provides a mix of ecosystem services (total of 110 currency units) of which 80 are used by the farmer and 30 are the final consumption of households.[64] All SNA production of the farmer (200) is recorded as final consumption of households. For simplicity, no other production, intermediate consumption or final consumption is recorded. It is to be noted that in the generation of ecosystem services, there is no recording of "inputs" from within the ecosystem. Such recording is not required for the purposes of developing a sequence of accounts focused on economic units.

A6.3 In both models, the rise in GDP occurs in relation only to the final consumption of ecosystem services that relate to non-SNA benefits. Many ecosystem services will be indirectly included in measures of final consumption when they are used by enterprises in the production of standard SNA outputs (e.g., food, clothing, recreation).

A6.4 Measures of GDP may be adjusted for both consumption of fixed capital (CFC) and ecosystem degradation, thus providing degradation-adjusted net domestic product.

A6.5 Under model A, flows of ecosystem services, flowing from ecosystems to relevant units as either intermediate or final consumption, are recorded in gross terms. In aggregate, the output of the economy rises by the full extent of ecosystem services, and GDP will rise to the extent that some of the ecosystem services are consumed as final consumption.

A6.6 Under model B, flows of ecosystem services are recorded in net terms inasmuch as "purchases" of ecosystem services for use in the production of products by the manager of the ecosystem (in this case, considered to be the producer of the ecosystem services) are not shown explicitly. It would be possible to introduce extra flows into model B so as to enable recording of all flows of ecosystem services in gross terms. As in model A, GDP rises to the extent that ecosystem services are consumed as final consumption.

A6.7 In standard capital accounting practice, consumption of fixed capital, the costs associated with the use of produced assets, is deducted from the income of the user of the asset. The logic of this deduction is clear, given that there is only one economic unit that supplies the capital service and there is only one capital service for each asset. However, in ecosystem accounting, the relationships between economic units and ecosystems are more complex. Consequently, as discussed above, alternative approaches to the allocation of ecosystem degradation to economic units must be considered.

64 The allocation is based on the assumed composition of the ecosystem services. Thus, the value of 80 for ecosystem services may be considered inputs to agricultural production and the value of 30 may be considered regulating services, such as air filtration, used by households.

Table A6.1
Simplified sequence of accounts for ecosystem accounting

	Model A				Model B		
	Farmer	Household	Ecosystem	**Total**	Farmer	Household	**Total**
Production and generation of income accounts							
Output—SNA	200			200	200		200
Output—non-SNA			110	110	30		30
Total output	200		110	310	230		230
Intermediate consumption—SNA	0		0	0	0		0
Intermediate consumption—non-SNA	80		0	80	0		0
Gross value added	120		110	230	230		230
Less consumption of fixed capital (SNA)	10			10	10		10
Less ecosystem degradation (non-SNA)			15	15	15		15
Degradation-adjusted net value added	110		95	205	205		205
Less compensation of employees—SNA	50			50	50		50
Degradation-adjusted net operating surplus	**60**		**95**	**155**	**155**		**155**
Allocation and use of income accounts							
Degradation-adjusted net operating surplus	60		95	155	155		155
Compensation of employees—SNA		50		50		50	50
Ecosystem transfers—non-SNA	80	30	-110	0	-30	30	0
Disposable income	140	80	-15	205	125	80	205
Less final consumption—SNA		200		200		200	200
Less final consumption—non-SNA		30		30		30	30
Degradation-adjusted net saving	**140**	**-150**	**-15**	**-25**	**125**	**-150**	**-25**

A6.8 In model A, the full amount of ecosystem degradation is attributed to the new ecosystem quasi-sector. This, in effect, follows standard capital accounting practice and assumes that the ecosystem is the sole supplier of ecosystem services and, as a producing unit, must incur the full impact of declines in its asset base. In model B, the farmer is assumed to be the sole supplier of ecosystem services (as manager of the ecosystem) and hence all ecosystem degradation is attributed to him or her.

A6.9 However, neither of these assumptions provides an all-encompassing perspective on the attribution of ecosystem degradation that may be anticipated. Under an activity-based allocation, it would be necessary to determine the economic units responsible for the degradation and adjust their income. Under a receiver-based allocation, as consideration would shift to the users of the ecosystem services, some ecosystem degradation would be attributed to households, reflecting their direct and indirect consumption of ecosystem services.

A6.10 It is important to recognize that in both models, the recording of flows of ecosystem services is quite distinct from that of flows of ecosystem degradation. Allowing for this difference enables a more complete and consistent recording of all ecosystem services—that is, provisioning, regulating or cultural—not only those of a particular type.

A6.11 Both models contain the entry "Ecosystem transfers", which is not a standard entry in the SNA. This entry accounts for the additional consumption of ecosystem services by each sector and its values sum to zero across the economy. The level of the transfers is higher in model A than in model B, reflecting the fact that in model A, all ecosystem services are purchased from the ecosystem quasi-sector. The inclusion of this entry indicates that the balancing item, "Net lending", recorded in the capital and financial accounts is consistent with the set of actual financial flows within the economy. Note that the recording of ecosystem transfers is not affected by choices related to the recording of ecosystem degradation.

A6.12 The application of model A appears to be a straightforward exercise, since the ecosystem is presented separately, as an adjunct to standard institutional units. Unfortunately, the actual depth of integration between ecosystems and economic activity means that isolating ecosystems may be difficult in practice. Of particular concern is the case where the current balance sheet of an economic unit contains assets that are also part of an ecosystem (e.g., timber resources). Model A requires, ideally, that the value of all ecosystem assets be attributed to the new quasi-sector for ecosystems. Additionally, model A requires a full gross measurement of ecosystem services, whereas in model B only additional non-SNA flows need be articulated.

A6.13 Model B adopts a more integrated view of the relationship between ecosystems and economic units. The key difference lies in the fact that adjustments for ecosystem degradation are made to the income of the producer rather than to the imputed income of the ecosystem. Thus, ecosystem degradation is attributed directly to a standard economic unit. However, this model requires the assumption that a specific institutional unit manages the ecosystem and is therefore responsible for the generation of ecosystem services. This assumption may be a weak one. It would be possible to partition the ecosystem asset across more than one institutional sector but this might not be a straightforward endeavour. Estimates of ecosystem degradation also need to be partitioned if more than one institutional unit is considered to be involved.

A6.14 An alternative model, representing something of a compromise between models A and B, could incorporate an ecosystem quasi-sector whose outputs would be only non-SNA ecosystem services. This type of recording requires a partitioning of ecosystem assets, ecosystem services and ecosystem degradation, which may be accomplished by first deriving the total value of the ecosystem and then deducting the existing values of relevant economic assets already included on the balance sheets of the standard institutional sectors. The resulting residual would be the value of the ecosystem asset attributed to the ecosystem quasi-sector. Utilization of the relationships between ecosystem service flows and economic units would enable attribution of ecosystem degradation.

A6.15 Overall, there is no straightforward means of choosing the structure of a sequence of ecosystem accounts. Neither model A nor model B (or possible variants thereof) presents information on all of the relevant flows as neatly as may be desirable so as to eliminate the need for various allocations or assumptions. One factor to consider is the recording of ecosystem restoration expenditure. If information on this expenditure is to be integrated into the sequence of accounts, it may be appropriate to keep this expenditure intact (i.e., to ensure that it clearly pertains to a specific ecosystem), instead of partitioning it across multiple ecosystem managers through a series of capital transfers.

Annex

Research agenda for SEEA Experimental Ecosystem Accounting

Introduction

A.1 SEEA Experimental Ecosystem Accounting provides a broad conceptual framework for ecosystem accounting. However, notwithstanding the important steps that have been taken, a number of conceptual and practical issues remain to be addressed. To advance ecosystem accounting, research is required on the conceptual issues that remain to be elaborated or are the subject of discussion. In addition, testing of the conceptual framework will provide valuable inputs into the ongoing development of concepts, methods and classifications related to ecosystem accounting. Given the multidisciplinary nature of ecosystem accounting, the advancement of the research agenda as well as the testing of SEEA Experimental Ecosystem Accounting will require engagement across disciplines and organizations.

A.2 The research agenda presented in the present annex provides a general overview of the main issues to be addressed. The issues have been organized according to broad research areas, which reflect the general focus of the work ahead. All of the issues are closely interconnected and need to be addressed in a coordinated fashion, taking into account the initiatives of countries and international organizations that are under way.

Areas of research

A.3 There are three proposed areas of research, each of which is discussed below:

(a) Physical ecosystem accounting;

(b) Monetary ecosystem accounting;

(c) Communication and dissemination.

Physical ecosystem accounting

A.4 This area of research aims to advance understanding of the classifications, concepts and data sources required for the physical measurement of ecosystem services and ecosystem condition and the application of these measures to accounts in physical terms. Some of this work relates to the research agenda for the SEEA Central Framework, including, for example, topics such as land-use and land-cover classifications, accounting for soil resources and the measurement of depletion of biological resources. A combined approach to these topics would be desirable.

A.5 This area of research encompasses work on:

- Delineating spatial units following the broad conceptual model outlined in SEEA Experimental Ecosystem Accounting, which should focus initially on spatial units for terrestrial areas (including rivers, lakes and other inland waters) and extend to units for marine areas and the atmosphere.
- Developing the classification of spatial units, in particular land-cover ecosystem functional units (LCEUs).
- Identifying possible geospatial sources of information such as remote-sensing data and other "big data" sources for ecosystem accounting.
- Investigating techniques for linking data related to ecosystem measurement to geo-referenced social and economic data. Such multidimensional geo-referencing may be considered within the context of delineating spatial units for ecosystems.
- Identifying the main ecosystem services and relevant indicators of service flow for each type of ecosystem (e.g., forests, agricultural land) including development of an understanding of the measurement of the supply, demand and distribution of ecosystem services and the associated benefits. This work should consider the appropriateness of the proposed Common International Classification of Ecosystem Services (CICES) and the general measurement boundaries related to ecosystem services, as discussed in chapter III.
- Identifying the main characteristics of ecosystems as they relate to the measurement of ecosystem condition and relevant indicators of condition for each type of ecosystem (e.g., forests, wetlands). This work should consider the links to delineation of spatial units.
- Considering the links between expected flows of ecosystem services and measures of ecosystem condition and extent, including assessment of relevant models and the connections to issues such as resilience and thresholds. This work should also advance understanding of ecosystem degradation in physical terms.
- Investigating different approaches to determining reference conditions for the assessment of ecosystem condition, based on practical experience in countries.
- Developing specific topics of research on measures related to biodiversity and carbon in the context of ecosystem accounting.
- Examining aggregation methods for both ecosystem services and ecosystem condition indicators, so as to derive measures across and within ecosystems, in conjunction with investigation of methods of downscaling and upscaling information.
- Examining the treatment of the so-called ecosystem disservices in ecosystem accounting, such as pest infestation and diseases.
- Considering the assessment of data quality and the accreditation of sources of data, particularly scientific and modelled data.

Monetary ecosystem accounting

A.6 This area of work focuses on the pricing and valuation of ecosystem services and ecosystem assets and the possible augmentation of the standard economic accounts of the SNA using such valuation. The issue of valuation of water has been included in the research agenda of the SEEA Central Framework. It would be beneficial for this issue to be discussed also in the context of ecosystem accounting.

A.7 This area encompasses work on:

- Clarifying the alternative ecosystem service pricing techniques and their relevance to determining (a) prices for ecosystem services connected to market goods and services; and (b) prices for ecosystem services connected to non-market goods and services. The choice of underlying assumptions for ecosystem accounting purposes (covering both economic and social approaches to valuation) and the general feasibility of implementation of these techniques (including any requirements for information in physical terms) should be identified.
- Applying information from emerging environmental markets, including payments for ecosystem services (PES), to the valuation of ecosystem services and ecosystem assets.
- Identifying ecosystem-related transactions and expenditures within the standard economic accounts and aligning these transactions with measurement of ecosystems in physical terms.
- Determining methods for the valuation of ecosystem assets and ecosystem degradation as well as for possible derivation of degradation-adjusted macroeconomic aggregates.
- Developing the sequence of accounts by institutional sector that incorporate flows relating to ecosystem services and ecosystem assets. This work should entail distinguishing between flows already within scope of the standard economic accounts and extensions to standard measurement boundaries, and should also entail considering options for the attribution of ecosystem degradation to institutional sectors and industry.
- Investigating extended national balance sheets, including consideration of overlaps between the valuation of individual environmental assets (especially land) and ecosystem assets. Links should be established with alternative measures of wealth. Consideration should also be given to establishing links with the recording of entries in the capital account and to the connections between flows related to ecosystem enhancement and land improvement.

Communication and dissemination

A.8 This area of work focuses on communicating the results of ecosystem accounting. This work should encompass:

- Developing combined presentations which provide ecosystem accounting information as evaluated against data from the SEEA Central Framework, the SNA and other sources.
- Proposing ecosystem accounting tables, dashboards, headline and composite indicators, maps and other communication tools.
- Illustrating the range of uses of ecosystem accounting information, which would, inter alia, focus on, but not be limited to, the analysis of trade-offs, for example, between alternative land uses.

Glossary

Introduction

The present annotated glossary provides definitions, descriptions and relevant connections for the key terms and concepts described in SEEA Experimental Ecosystem Accounting. In some cases, it provides some background clarification regarding the choice of terms and also notes cases where other terms are often used to describe the same or similar concepts.

The content is intended to facilitate a further understanding of the terms and concepts used, as well as to enhance the productiveness of exchanges between researchers, since it is quite common for the same term to be associated with different concepts and for different terms to refer to the same concept.

This glossary may be read in conjunction with the list of references structured according to broad topic which offers an overview of the literature that provides the foundation for the synthesis presented in SEEA Experimental Ecosystem Accounting. Additional terms, particularly those related to accounting principles and accounting entries, are included in the glossary of the SEEA Central Framework.

Unless otherwise stated, the paragraph numbers in parentheses refer to the text of SEEA Experimental Ecosystem Accounting.

Definitions and descriptions

A

Abiotic services: Flows from the environment to economic and other human activity that do not arise from biophysical processes and other interactions within and between ecosystems.

The main examples are flows of mineral and energy resources from underground deposits, harnessing of energy from the sun for the growing of crops and for use as a source of renewable energy, the movement of wind and tides which can be captured to serve as sources of energy, and the provision of space in areas of land and water for the undertaking of economic and other human activity. (3.20-3.22)

See also Ecosystem services

B

Basic spatial unit (BSU): A basic spatial unit (BSU) is a small area. Ideally, a BSU is formed by delineating tessellations (small areas, e.g., areas of 1 square kilometre), typically by overlaying a grid on a map of the relevant territory; but BSUs may also be land parcels delineated by a cadastre or by using remote-sensing pixels. (2.53)

The BSU is the smallest unit in the model used to define areas for the purposes of ecosystem accounting. BSUs can be aggregated to form land-cover/ecosystem functional units (LCEUs) and ecosystem accounting units (EAUs).

See also Ecosystem accounting unit, Land-cover/ecosystem functional unit

Beneficiaries: Individual and economic units (enterprises, households, governments and units in the rest of the world) that receive the benefits to which ecosystem services contribute. (2.76, 3.8, 3.9, 3.33)

See also Benefits, Ecosystem services, Economic unit

Benefits: Goods and services that are ultimately used and enjoyed by people and which contribute to individual and societal well-being. (2.19-2.21)

In SEEA Experimental Ecosystem Accounting, benefits are distinguished from ecosystem services (which contribute to the generation of benefits) and from well-being (to which benefits contribute).

While in many studies, the terms "benefits" and "ecosystem services" are defined synonymously, this is not the approach taken in SEEA Experimental Ecosystem Accounting. Further, in some studies, the term "goods" refers to benefits as conceptualized here. The term "goods" is not used here, in order to prevent confusion with the same term as used in economic statistics, where it relates to the production, consumption and accumulation of tangible items (e.g., as in the phrase "production of goods and services").

Two broad types of benefits are described in SEEA Experimental Ecosystem Accounting. *SNA benefits* encompass the products (goods and services) produced by economic units (e.g., food, clothing, shelter, entertainment) within the production boundary defined by the SNA. SNA benefits include goods produced by households for their own consumption.

Non-SNA benefits are not generated by economic production processes, as defined in the SNA. Rather, they encompass ecosystem services that do not contribute to the production of SNA goods and services.

See also Ecosystem services

Biocarbon: Carbon stored in the biosphere, in living and dead biomass and in soils. (4.97)

Biodiversity: The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. (Convention on Biological Diversity, article 2, entitled "Use of Terms")

Generally, in SEEA Experimental Ecosystem Accounting, the measurement of biodiversity is focused on the assessment of diversity of species, although changes in the diversity of ecosystems is also an important output, derived from the measurement of changes in ecosystem extent and condition.

See also Ecosystem characteristics

C

Consumer surplus: The gain obtained by consumers because they are able to purchase a product at a market price that is lower than the highest price they would be willing to pay. (5.19)

See also Exchange value, Producer surplus, Welfare economic value

Cultural services: The intellectual and symbolic benefits that people obtain from ecosystems through recreation, knowledge development, relaxation and spiritual reflection. (3.4(c))

See also Ecosystem services, Provisioning services, Regulating services

D

Degradation (see Ecosystem degradation)

Depletion: In physical terms, this is the decrease in the 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. (SEEA Central Framework, 5.76)

Depletion is distinct from ecosystem degradation inasmuch as it refers to the decrease in a specific individual environmental asset rather than to the decline in the functioning of an ecosystem asset as a whole. Nonetheless, close connections are likely to exist between depletion and ecosystem degradation in specific spatial areas.

Note that depletion relates only to decreases in natural resources (i.e., it does not cover cultivated biological resources) and does not apply to land (although there may be depletion of soil resources, e.g., through erosion).

Depletion may be estimated in monetary terms.

See also Ecosystem degradation, Environmental assets, Natural resources; SEEA Central Framework, section 5.4.2 and annex A5.1

E

Economic unit: An economic unit—referred to as an institutional unit in national accounting—is an economic entity that is capable, in its own right, of owning assets, incurring liabilities, and engaging in economic activities and in transactions with other entities. (2008 SNA 4.2)

Institutional units may be either households, or legal or social entities that are recognized independently of the people that own or control them. Groupings of institutional units that are similar in their purposes, objectives and behaviours are called institutional sectors. Following the SNA, five types of institutional sector are recognized: households, non-financial corporations, financial corporations (in the SEEA, financial and non-financial corporations are usually assigned to a single category: corporations), general government and non-profit institutions serving households.

An enterprise is the view of an institutional unit as a producer of goods and services. An establishment is an enterprise, or part of an enterprise, that is situated in a single location and in which only a single productive activity is carried out or in which the principal productive activity accounts for most of the value added. An industry consists of a group of establishments engaged in the same, or similar, kinds of activity. Examples include agriculture, manufacturing, education, finance and retail activity. (2008 SNA, 5.1-5.2)

For more details, see 2008 SNA, chapters 4 and 5 and SEEA Central Framework, chapter II.

Ecosystem: A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. (Convention on Biological Diversity, article 2, entitled "Use of terms")

Ecosystems may be identified at different spatial scales and are commonly nested and overlapping. Consequently, for accounting purposes, ecosystem assets are defined through the delineation of specific and mutually exclusive spatial areas.

See also Ecosystem assets, Ecosystem accounting unit (EAU), Land-cover/ecosystem functional unit (LCEU).

Ecosystem accounting unit (EAU): Large, mutually exclusive spatial areas delineated on the basis of accounting. Generally, they will reflect a landscape perspective. Factors considered in their delineation include administrative boundaries, environmental management areas, socioecological systems and large-scale natural features (e.g., river basins). (2.65)

A hierarchy of EAUs may be built up from a landscape scale to encompass larger subnational and national boundaries. An EAU at the landscape level may be considered to reflect ecosystem assets. EAUs are the highest level of the spatial model used to define areas for the purposes of ecosystem accounting.

See also Basic spatial unit (BSU), Land-cover/ecosystem functional unit (LCEU), Ecosystem assets

Ecosystem assets: Spatial areas comprising a combination of biotic and abiotic components and other elements which function together. (2.31, 4.1)

Depending on the analysis being conducted, an ecosystem asset may be defined as containing either a specific combination of ecosystem characteristics (e.g., a tropical rainforest represented by an LCEU) or areas that comprise a variety of combinations of ecosystem characteristics (e.g., a river basin encompassing wetlands, agriculture and settlements represented by an EAU).

Ecosystem assets should be distinguished from (a) the various individual components (e.g., plants, animals, soil, water bodies) that are contained within a spatial area; and (b) other ecosystem characteristics (e.g., biodiversity, resilience). In different contexts and discussions, each of these components and other characteristics may be considered assets in their own right (e.g., in the SEEA Central Framework, many individual components are considered to be individual environmental assets). However, for ecosystem accounting purposes, the focus is on the functioning system as the asset.

The term "ecosystem assets" has been adopted rather than "ecosystem capital", since the word "assets" is more aligned with the terminology employed by the SNA and also better conveys the intention in ecosystem accounting of encompassing measurement in both monetary and physical terms. In general, however, the terms "ecosystem assets" and "ecosystem capital" may be considered synonymous.

See also Ecosystem, Ecosystem accounting unit (EAU), Land-cover/ecosystem functional unit (LCEU), Ecosystem or ecological capital, Environmental assets, Natural capital, Natural resources

Ecosystem capacity: The concept of ecosystem capacity is not defined from a measurement perspective in SEEA Experimental Ecosystem Accounting. It is linked, instead, to the general model of ecosystem assets and ecosystem services as described. In general terms, ecosystem capacity refers to the ability of a given ecosystem asset to sustainably generate a set of ecosystem services into the future. While this general concept is highly relevant to ecosystem assessment, definitive measurement of ecosystem capacity requires the selection of a particular basket of ecosystem services and in this regard measures of ecosystem capacity are more likely to relate to consideration of a range of alternative ecosystem use scenarios than to a single basket of ecosystem services.

See also Ecosystem assets, Ecosystem condition, Ecosystem services

Ecosystem characteristics: Factors related to the ongoing operation of the ecosystem and its location. Key characteristics of the operation of an ecosystem are its structure, composition, processes and functions. Key characteristics of the location of an ecosystem are its extent, configuration, landscape forms, and climate and associated seasonal patterns. Ecosystem characteristics also relate strongly to biodiversity at a number of levels. (See sect. 2.1 for more details)

There is no classification of ecosystem characteristics, since, while each characteristic may be distinct, they are commonly overlapping. In some situations, it might appear that the generic term "characteristics" would be replaced with a term such as "components" or "aspects" as being more useful. However, the intention in using "characteristics" is to take into account all of the dimensions encompassed by the broadest concept of an ecosystem.

See also Ecosystem, Ecosystem assets, Ecosystem condition

Ecosystem condition: The overall quality of an ecosystem asset in terms of its characteristics. (2.35)

Measures of ecosystem condition are generally combined with measures of ecosystem extent to provide an overall measure of the state of an ecosystem asset. Since ecosystem condition also underpins the capacity of an ecosystem asset to generate ecosystem services, changes in ecosystem condition will impact on expected ecosystem service flow.

See also Ecosystem assets, Ecosystem characteristics, Ecosystem extent, Expected ecosystem service flow

Ecosystem conversion: An ecosystem conversion reflects changes in the extent or composition of an ecosystem asset where there is a shift from one ecosystem type to another that is considered significant or irreversible (e.g., changes owing to deforestation carried out to create agricultural land). (4.32)

Ecosystem degradation: The decline in an ecosystem asset over an accounting period due to economic and other human activity. It is generally reflected in declines in ecosystem condition and/or declines in expected ecosystem service flow. Measures of ecosystem degradation will be influenced by the scale of analysis, the characteristics of the ecosystem asset, and the expectations regarding the use of the ecosystem asset in the future. Ecosystem degradation may be measured in physical and monetary terms. (For details, see 4.31-4.37)

Ecosystem enhancement: The increase and/or improvement in an ecosystem asset that is due to economic and other human activity. (4.38)

Ecosystem extent: The size of an ecosystem asset, commonly in terms of spatial area. (2.38) In cases where an ecosystem asset comprises a number of areas with different combinations of ecosystem characteristics (i.e., the ecosystem asset is a type of EAU), then the ecosystem extent of an area with a specific combination of characteristics may be measured as a proportion of the total area of the ecosystem asset. For example, the extent of wetlands may be 30 per cent of the area of a river basin.

See also Ecosystem assets, Ecosystem condition

Ecosystem goods and services (see Ecosystem services)

Ecosystem or ecological capital: This is not explicitly defined in SEEA Experimental Ecosystem Accounting. Instead, the term "ecosystem assets" is employed to refer to the individual spatial areas that are the focus of measurement. In many discussions, the term "ecosystem capital" may be considered to relate to a broader concept of the stock that provides a foundation for future well-being, together with human capital, produced/man-made capital and social capital. These various types of capital are regularly brought together in models of sustainable development and wealth accounting.

While there is no difference between the application of the terms "capital" and "assets" in SEEA Experimental Ecosystem Accounting and their use in other contexts (e.g., wealth accounting), some care is needed to understand the potentially different measurement scopes of these types of capital/assets. Specific considerations concern the treatment of mineral and energy resources and the distinction between natural and cultivated biological resources.

See also Ecosystem assets, Environmental assets, Natural capital, Natural resources

Ecosystem services: The contributions of ecosystems to benefits used in economic and other human activity. (2.23)

The definition of ecosystem services used in SEEA Experimental Ecosystem Accounting involves distinctions among (a) the ecosystem services, (b) the benefits to which they contribute and (c) the well-being that is ultimately affected. Ecosystem services should also be distinguished from the ecosystem characteristics and functions and processes of ecosystem assets.

Ecosystem services are considered to exist only when a contribution to a benefit is established. Consequently, the definition of ecosystem services excludes the set of flows commonly referred to as supporting or intermediate services. These flows include intra- and inter-ecosystem flows and the contribution of all ecosystem characteristics to ecosystem processes.

A range of terms are used to refer to the concept of ecosystem services as defined here, the most common being "ecosystem goods and services" and "final ecosystem services". These two terms highlight particular aspects of that concept. In the context of the first, ecosystem services include flows of tangible items (e.g., timber, fish) in addition to intangible services. In the context of the second, only those ecosystem services that contribute to a benefit—i.e., that are final outputs of the ecosystem—are within scope.

Since ecosystem services as defined in SEEA Experimental Ecosystem Accounting exclude abiotic services, they do not encompass the complete set of flows from the environment. A complete set of flows may be covered by the term "environmental goods and services".

Three main types of ecosystem services are distinguished here: provisioning services, regulating services and cultural services. The Common International Classification of Ecosystem Services (CICES) is an interim classification.

See also Abiotic services, Provisioning services, Regulating services, Cultural services, Inter-ecosystem flows, Intra-ecosystem flows

Environmental assets: The naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity. (SEEA Central Framework, 2.17)

This definition of environmental assets is intended to be broad and encompassing. As explained in the SEEA Central Framework, the measurement of environmental assets can be considered from two perspectives. The first perspective encompasses individual components, i.e., individual environmental assets, which provide materials and space for all economic activities. Examples include land, soil, water, timber, aquatic, and mineral and energy resources.

The second perspective on environmental assets encompasses ecosystems. However, the scope of environmental assets is not the same as that of ecosystem assets, since the former includes mineral and energy resources which are excluded from the scope of the latter.

Also, the broad scope of environmental assets extends beyond natural resources, as it includes produced assets such as cultivated crops and plants (including timber and orchards), livestock and fish in aquaculture facilities.

In the SEEA Central Framework, the measurement scope of environmental assets is broader in physical terms than in monetary terms, as the boundary in monetary terms is limited to those environmental assets that have an economic value in monetary terms, following the market valuation principles of the SNA.

See also Ecosystem assets, Natural resources; SEEA Central Framework, chapter V

Exchange value: This reflects the actual outlays and revenue for all quantities of a product that are transacted. It is equal to the market price multiplied by the quantity transacted. It is based on the assumption that all purchasers pay (and producers receive) the same price on average, and hence excludes consumer surplus. Exchange values are those that underpin national and business accounting frameworks, as they can be estimated based on observed transactions. (5.21)

See also Market prices, Consumer surplus

Expected ecosystem service flow: An aggregate measure of future ecosystem service flows from an ecosystem asset for a given basket of ecosystem services. (2.40)

In general terms, the measure of expected ecosystem service flows reflects an assessment of the capacity of an ecosystem asset to generate ecosystem services in the future. However, the focus is on the generation of a specific, expected combination of ecosystem services (the given basket) which it may or may not be possible to produce on a sustainable basis. Thus, the measure does not necessarily reflect sustainable or optimal scenarios of future ecosystem asset use. At the same time, the forming of expectations regarding future ecosystem service flows requires information on likely changes in ecosystem condition, noting that the relationship between condition and ecosystem service flow is likely to be complex and non-linear.

See also Ecosystem services, Ecosystem assets, Ecosystem condition

F

Final ecosystem services (see Ecosystem services)

G

Geocarbon: Carbon stored in the geosphere. It can be disaggregated into: oil, gas, coal resources, rocks (primarily limestone) and minerals (e.g., carbonate rocks used in cement production, methane clathrates and marine sediments). (4.97)

I

Individual environmental assets (see Environmental assets)

Inter-ecosystem flows: Flows between ecosystem assets that reflect ongoing ecosystem processes. (2.13) The flows of water between ecosystem assets by way of rivers are one example.

These flows may relate directly or indirectly to flows of ecosystem services. Most commonly, inter-ecosystem flows are flows considered to be supporting or intermediate services.

See also Ecosystem services, Intra-ecosystem flows

Intermediate ecosystem services (see Ecosystem services, Inter-ecosystem flows, Intra-ecosystem flows)

Intra-ecosystem flows: Flows within ecosystem assets that reflect ongoing ecosystem processes. (2.13) One example is nutrient cycling.

These flows may relate directly or indirectly to flows of ecosystem services. Most commonly, intra-ecosystem flows are flows considered to be supporting or intermediate services.

See also Ecosystem services, Inter-ecosystem flows

L

Land cover: The observed physical and biological cover of the Earth's surface and includes natural vegetation, abiotic (non-living) surfaces and inland water bodies, such as rivers, lakes and reservoirs. (SEEA Central Framework, 5.257)

Land cover/ecosystem functional unit (LCEU): For most terrestrial areas, the area and, by extension, the LCEU should satisfy a pre-determined set of criteria relating to the characteristics of an ecosystem. Examples of factors include land-cover type, water resources, and soil type. (2.57)

The LCEU may be considered to represent ecosystem assets and may often fulfil the common conception of ecosystems (e.g., forests, wetlands, deserts). Generally, LCEUs constitute the middle level of the model that is used to define areas for the purposes of ecosystem accounting. Thus, an ecosystem accounting unit (reflecting a landscape perspective) will generally encompass a number of different LCEU types.

See also Basic spatial unit, Ecosystem accounting unit, Ecosystem assets

M

Market prices: The amount of money that willing buyers pay to acquire goods, services or assets from willing sellers. (5.37; 2008 SNA, 3.119)

For details, see SEEA Central Framework, section 2.7, and the 2008 SNA, chapter VI.

See also Exchange value

N

Natural capital: The term "natural capital" is not defined in SEEA Experimental Ecosystem Accounting. Commonly, the term refers to all types of environmental assets, as defined in the SEEA Central Framework. Used in this way, natural capital has a broader scope than that of ecosystem assets, as defined in SEEA Experimental Ecosystem Accounting, since it includes mineral and energy resources.

Generally, the concept of natural capital incorporates a broad perspective on the set of services from ecosystems which are in line with the accounting for ecosystem assets described in SEEA Experimental Ecosystem Accounting. In this regard, notwithstanding the alignment in biophysical terms, natural capital may be considered a broader measure than the measures of environmental assets described in the SEEA Central Framework, which are limited to consideration of material/SNA benefits.

It is to be noted that, while natural capital would usually incorporate all ecosystem assets, there is ample evidence to indicate that very few, if any, ecosystems are not influenced by humans and therefore there are few ecosystem assets that may be considered purely "natural". See Benefits, Ecosystem assets, Ecosystem or ecological capital, Environmental assets, Natural resources

Natural resources: All natural biological resources (including timber and aquatic resources), mineral and energy resources, soil resources, and water resources. (SEEA Central Framework, 5.18)

In the SEEA, unlike the SNA, natural resources exclude land, which is considered a distinct type of environmental asset. (See SEEA Central Framework, 5.19-5.23)

Following the SNA, natural resources are defined in the SEEA to include only non-produced environmental assets, i.e., assets that are not considered to have come into existence as outputs of processes that fall within the production boundary of the SNA. A distinction is thus made between "natural" and "cultivated" environmental assets.

See also Environmental assets, Ecosystem assets, Natural capital

Non-SNA benefits (see Benefits)

P

Payments for ecosystem services (PES): Generally, voluntary and conditional transactions over well-defined ecosystem services between at least one supplier and one user. (6.18)

Producer surplus: The amount by which producers benefit by selling at a market price that is higher than the lowest price that they would be willing to sell for, which is a function of their production costs. (5.19)

See also Consumer surplus

Provisioning services: Contributions to the benefits produced by or in the ecosystem, for example, a fish, or a plant with pharmaceutical properties. The associated benefits may be provided in agricultural systems, as well as within semi-natural and natural ecosystems. (3.4 (a))

See also Ecosystem services, Regulating services, Cultural services

R

Recreational services (see Cultural services)

Regulating services: These result from the capacity of ecosystems to regulate climate, hydrologic and biochemical cycles, Earth surface processes and a variety of biological processes. (3.4 (b))

Regulating services are also commonly referred to as “regulation and maintenance services”. In the context of the definition of ecosystem services used in SEEA Experimental Ecosystem Accounting, these two terms are synonymous.

See also Ecosystem services, Provisioning services, Cultural services

S

SNA benefits (see Benefits)

Species abundance: A measure of the absolute number of a particular species in an area. (4.122)

Species richness: A measure of the number of different species in an area. (4.122)

Supporting services (see Ecosystem services, Inter-ecosystem flows, Intra-ecosystem flows)

W

Welfare economic value: The total (or gross) economic gain associated with the quantities of a product that are transacted. They include both the consumer and producer surplus. The concept of welfare economic value differs from that of exchange value as a result of the inclusion in the former of consumer surplus. (5.3.2)

Welfare economic values may also reflect the net economic gain, which is derived, equivalently, as either the total economic gain less the costs of production, or the consumer surplus plus the producer surplus.

See also Exchange value, Consumer surplus, Producer surplus

References

The following list of references has been structured by broad topic within the overall subject area of ecosystem accounting. This approach is intended to aid those wishing to develop their understanding of the many perspectives to ecosystem accounting and, to this end, various relevant examples of published research have been provided. The topics used align broadly with the chapter structure of SEEA Experimental Ecosystem Accounting.

The topics encompass:

A. Measurement, classification and analysis of ecosystem services;

B. Analysing ecosystem assets and ecosystem dynamics (in physical terms);

C. Accounting for carbon;

D. Measurement of biodiversity;

E. Valuation of ecosystem assets and ecosystem services;

F. Ecosystem and wealth accounting;

G. National- and broad-scale ecosystem accounting and related initiatives;

H. General references.

The references covered are not limited to those that have been of direct use in informing the preparation of SEEA-Experimental Ecosystem Accounting. Instead, the intent has been to offer a broad base of references which reflect the diverse contributions of many researchers in different topic areas. In particular, although the development of ecosystem accounting as described in the present publication is relatively recent, the work builds on long-standing research in several different fields. While broad in coverage, the list of references is not intended to be exhaustive and researchers are encouraged to seek complementary reference material.

In the preparation of SEEA-Experimental Ecosystem Accounting, three expert meetings on ecosystem accounts were held, in Copenhagen, London and Melbourne. Numerous papers were prepared for these meetings, each contributing to the underlying base of information used to draft the text. Some specific papers are cited below. The papers and presentations submitted to the expert meetings are available from the following links:

Expert meeting held in Copenhagen, Denmark: May 2011

http://unstats.un.org/unsd/envaccounting/seearev/meetingMay2011/lod.htm

Expert meeting held in London, United Kingdom: December 2011

http://unstats.un.org/unsd/envaccounting/seeaLES/egm/lod.htm

Expert meeting held in Melbourne, Australia: May 2012

http://unstats.un.org/unsd/envaccounting/seeaLES/egm2/lod.htm

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