System of Environmental-Economic Accounting 2012

Experimental Ecosystem Accounting

White cover publication, pre-edited text subject to official editing

European Commission • Organisation for Economic Co-operation and Development • United Nations • World Bank

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Preface

Ecosystem accounting is a relatively new and emerging field dealing with integrating complex biophysical data, tracking changes in ecosystems and linking those 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, there has been an increasing urgency to advance this emerging field of statistics.

Although considerable experience exists in related areas of statistics such as land cover and land use statistics, the integration of these and other information into an ecosystem accounting framework is new. Also, there is considerable existing expertise in the ecosystem sciences and economics fields that is relevant, and again it is the focussing of these different areas of expertise on the proposed ecosystem accounting approach that is new.

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 an important first step in the development of a statistical framework for ecosystem accounting. It further 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. In taking these steps the United Nations Statistical Commission recognized the growing policy demand for information about ecosystems and the linkages to economic and other human activity.

SEEA-Experimental Ecosystem Accounting provides a synthesis of the current knowledge in this area and provides a starting point for the development of ecosystem accounting at national and sub-national levels. It represents an important step forward on ecosystem accounting, providing a common set of terms, concepts, accounting principles and classifications; an integrated accounting structure of ecosystem services and ecosystem condition in both physical and monetary terms; and the recognition of spatial areas as forming the basic focus for measurement.

The framework and associated accounts described in SEEA-Experimental Ecosystem Accounting are a complement to the conceptual framework and accounts presented in the international statistical standard for environmental-economic accounting – the SEEA-Central Framework. Its complementary nature lies in four main areas: (i) the use of the same accounting principles, accounting structures and classifications thus allowing the measurement of ecosystem conditions and ecosystem services in conjunction with each other and in conjunction with standard measures of economic activity; (ii) the use of a systemic view of relationships between the individual environmental assets (for example, timber, water, and soil resources) that are defined in the SEEA-Central Framework; and (iii) the capacity to undertake assessment of environmental impacts of economic and other human activity to complement the measurement of environmental pressures that is a general focus of accounts in the SEEA-Central Framework and (iv) the use of a rigorous spatially based approach to measurement that complements the generally national level focus of accounting in the SEEA-Central Framework.

In this context the development of ecosystem accounting should be envisaged as an enhancement within the broad SEEA framework rather than an alternative or competing approach to environmental-economic accounting. Together, the SEEA-Central Framework and SEEA-Experimental Ecosystem

Accounting provide the potential to describe in a comprehensive manner the relationship between the environment and economic and other human activity.

Since SEEA-Experimental Ecosystem Accounting is not an international standard there is no expectation or requirement that countries implement ecosystem accounting within their set of official statistics. At the same time, in line with the encouragement of the United Nations Statistical Commission, it is anticipated that countries will test and experiment with ecosystem accounting, or specific aspects of it, in the coming years.

To support such efforts and to provide an 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 is also recognized that considering 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.

There is broad interest in ecosystem accounting beyond the statistical community and there are many projects and initiatives at a corporate, sub-national, national and international level that involve aspects related to ecosystem accounting. In broad terms the ecosystem accounting framework described in SEEA Experimental Ecosystem Accounting has the capacity to connect to and support these various initiatives. Consequently, it is important that countries who undertake testing and research in this area seek to draw input from and build relationships with these other initiatives.

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 UNSC at its thirty-eighth session in 2007. The UNCEEA 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 Secretariat for UNCEEA. Regular oversight of the project was provided by the Bureau of the UNCEEA.

The development of the technical input to SEEA-Experimental Ecosystem Accounting was developed through a series of meetings involving 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. In addition, members of the London Group on Environmental Accounting, who led the technical development for the SEEA-Central Framework, were able to play a general oversighting role in terms of the links between the two documents.

The contributions from these meetings of experts and from the London Group members were brought together by the editor and the editorial board of SEEA-Experimental Ecosystem Accounting. The editorial board, established in March 2012, provided technical advice and direction to the editor who drafted the text. 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 a broad, public consultation process was conducted based on revised draft chapters and a final draft taking on board the resulting feedback was submitted to the UNSC in February 2013 for their consideration.

Acknowledgements

Background

SEEA-Experimental Ecosystem Accounting is the result of a process that was notable for its transparency and the wide involvement of the international statistical community, economists, scientists, policy makers and others. The process comprised five steps.

a. identifying and obtaining agreement on the issues to be considered in the drafting of SEEA-Experimental Ecosystem Accounting:

b. research into these issues and presenting the proposals for addressing the issues;

c. consideration of the issues and proposals by experts and agreement on provisional draft text;

d. consultations with countries and experts on specific issues as well as complete chapters; incorporating comments received though the consultation and preparation of a final draft of SEEA-Experimental Ecosystem Accounting; and

e. presentation of a draft to the Statistical Commission in 2013 who in its commission report "[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".

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

The process of drafting SEEA-Experimental Ecosystem Accounting involved the UNCEEA; 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, policy and related fields from multiple regions of the world. As could be expected of a product of such a complex and sustained process, SEEA-Experimental Ecosystem Accounting reflects many diverse contributions.

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

The Bureau of the UNCEEA, comprised of representatives elected among its members and acting under delegated authority from the UNCEEA, managed and coordinated the preparation of SEEA-Experimental Ecosystem Accounting.

The UNCEEA and its Bureau, which was formed in 2008, were chaired by Peter Harper (Australia, 2009-2013).

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

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

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

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

The following served as observers to UNCEEA: Peter Cosier (Wentworth Group of Concerned Scientists Australia) and Markus Lehman (CBD).

Experts in ecosystem accounting from international organizations who regularly provided substantive contributions were as follows:

Brian Newson and Anton Steurer (Eurostat)

Jock Martin and Jean Louis Webber (European Environment Agency)

Alessandra Alfieri and Ivo Havinga (United Nations Statistics Division)

Glenn-Marie Lange (World Bank)

Other staff members of international organizations who contributed substantively were:

Julian Chow, Daniel Clarke, Magdolna Csizmadia, Anthony Dvarskas, Ricardo Martinez-Lagunes, and Sokol Vako (United Nations Statistics Division)

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

The Editorial Board

The SEEA Experimental Ecosystem Accounting Editorial Board provided technical guidance to the drafting of the text and expert advice on the resolution of technical issues. The Editorial Board 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 Environmental Agency), Anton Steurer (Eurostat) and Glenn-Marie Lange (World Bank). Alessandra Alfieri (UNSD) provided the secretariat to the Editorial Board.

Expert Group Meetings

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 (EEA), in December 2011 in London hosed by the Office for National Statistics and the Department for Environment, Food and Rural Affairs of the United Kingdom, and in May 2012 in Melbourne hosted by the Australian Bureau of Statistics, the Bureau of Meteorology and the Department of Sustainability and Environment of Victoria.

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

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 EEA.

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 Garnåsjordet (Norway), Mohammed Al-Marzouqi and Michael Nagy (Oman), Eliana Quispe (Peru), Candido Astrologo (Philippines), Andrey Tatarinov (Russia), Tracey Lyn Cumming (South Africa), Alexander Girvan (Trinidad & Tobago), Catherine Connolly (United Kingdom), Dennis Fixler and Steve Landefeld (USA), Nguyen Tuan Anh (Viet Nam), Judith Ajani (Australian National University), Braulio Ferreira de Souza Dias (CBD), Geoffrey Heal (Columbia University), Jana Tafi (Consultant), Jean-Louis Weber (EEA), Pedro Diaz, Brian Newson and Walter Radermacher (Eurostat), Gary Jones (FAO), Thomas Lovejoy (Heinz Center), Marco Cangiano (New York University), Shamshad Akhtar (UNDESA), Charles Mc. Neill and Tim Scott (UNDP),Robert Vos (UNDPAD), Matthias Bruckner, Keneti Faulalo and David O'Connor (UNDSD), Rodney Smith (University of Minnesota), Alessandra Alfieri, Ivo Havinga, Eszter Horvath and Carl Obst (UNSD) and Glenn-Marie Lange (World Bank).

The London Group on Environmental Accounting

The London Group on Environmental Accounting discussed issues related to SEEA-Experimental Ecosystem Accounting at it 18th meeting held in Ottawa, Canada and hosted by Statistics Canada. The London Group was chaired by Sjoerd Schenau on behalf of Mark de Haan (Statistics Netherlands).

The following people participated in the 18th 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

Other consultations also informed the process. These included a group of experts on economic valuation whose members included: Alessandra Alfieri, Francisco Alpizar, Giles Atkinson, Ed Barbier, Ian Batemen, Ole Berner, Jim Boyd, Julian Chow, Daniel Clarke, Partha Dasgupta, Michael Davies, Haripriya Gundimeda, Kirk Hamilton, Ivo Havinga, Geoffrey Heal, Lars Hein, Pushpam Kumar, Glenn Mari Lange, Karl-Goran Maler, Anil Markandya, Peter May, Urvashi Narain, William Nordhaus, Paulo Nunes, Carl Obst, Sandra Paulsen, Charles Perrings, Michele Pittini, Steve Polasky, Taylor Ricketts, Manik Shrestha, Priya Shyamsundar, David Simpson, Gulab Singh, Michael Smedes, Rodney Smith, Gary Stoneham, Sokol Vako, Jeffrey Vincent and Kim Zieschang.

Country contributions

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 consultations 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 which mandated the formation of UNCEEA.

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

List of abbreviations and acronyms

BSU	basic spatial unit
CBD	Convention on Biological Diversity
CICES	common international classification of ecosystem services
CO_2	carbon dioxide
COP	conference of the parties
EAU	ecosystem accounting unit
EEZ	exclusive economic zone
EGSS	environmental goods and services sector
EPEA	environmental protection expenditure accounts
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 the Conservation of Nature
LCCS 3	Land Cover Classification System, version 3
LCEU	land cover/ecosystem functional unit
MA	Millennium Ecosystem Assessment
NPISH	non-profit institutions serving households
NPV	net present value
NSO	national statistical office
NTFP	non-timber forest products
OECD	Organisation for Economic Co-operation and Development
PES	payments for ecosystem services
PM	particulate matter
REDD	Reduced Emissions from Deforestation and Degradation
SEEA	System of Environmental-Economic Accounting
SNA	System of National Accounts
TEEB	The Economics of Ecosystem 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
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UNSC	United Nations Statistical Commission

I: Introduction

1.1 What is 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. "Ecosystems are a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit."[1] The scale of ecosystem accounting may vary from specific land cover types, such as forests, to larger integrated areas such as river basins, and includes areas that may be considered relatively natural and those that may be heavily influenced by human activity, such as agricultural areas.

1.2 Ecosystem accounting goes beyond other approaches to ecosystem analysis and assessment through the explicit linking of ecosystems to economic and other human activity. The links are seen both in terms of the services provided by ecosystems and also in 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 reflecting 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 also in relation to a range of other environmental, economic and social information

1.3 A prime motivation for ecosystem accounting is that the separate analysis of ecosystems and the economy does not reinforce the vital nature of the relationship between humans and the environment in which we live. The standard approaches to the measurement of the economy focus largely on economic and other human activity that is reflected in the activity of markets. Ecosystem accounting aims to shed light on the non-market activity that relates to ecosystems and integrate this information with relevant market related data. It is hoped that individual and social decisions concerning the use of the environment may be better informed by developing information sets based on recognition of the relationship between ecosystems and economic and other human activity.

1.4 In this broad context, the System of Environmental-Economic Accounting (SEEA) Experimental Ecosystem Accounting is an integrated statistical framework for organising biophysical data, measuring ecosystem services, tracking changes in ecosystem assets and linking this information to economic and other human activity. SEEA Experimental Ecosystem Accounting provides a complementary perspective to the accounting approaches described in the SEEA Central Framework but does not have the status of an international statistical standard.

1.5 SEEA Experimental Ecosystem Accounting is based on a synthesis of measurement concepts from a number of disciplines and is intended to be used to commence and support work on

[1] Convention on Biological Diversity (2003), Article 2, Use of Terms.

ecosystem accounting and to facilitate the exchange of experiences in the testing of various aspects of ecosystem accounting. Without a synthesis of various concepts and terms, the ability to communicate effectively across multi-disciplinary programs of work in this area would be significantly diminished. Indeed, the participants in the various disciplines are well aware of the need for further harmonisation in terminology and definitional coverage even though the number of core concepts is, in reality, not extensive. The coherent and integrated approach presented in SEEA Experimental Ecosystem Accounting should be a particularly useful foundation in this regard.

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

1.7 Ecosystem accounting as described here encompasses measurement of the contribution of ecosystems to standard measures of economic activity, such as GDP and national income, and measurement of the role that ecosystems play 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 the accounting approach is its capacity to accommodate a broader scope for the analysis of the role of the environment within the same broad logic that is applied to the standard measurement of the economy.

1.8 The extensions beyond standard approaches to economic and ecosystem measurement require the involvement of multiple disciplines. The development of an ecosystem accounting framework as described here has reflected such a multi-disciplinary effort. The ongoing work to test and establish the relevant statistical infrastructure, to organise and compile relevant information, and to adopt these more extensive information sets into decision making will continue to require engagement across disciplines and organisations.

1.9 Accounting for ecosystems in physical (i.e. non-monetary) terms[2] is a key feature of the SEEA Experimental Ecosystem Accounting. There is a significant amount of information in physical terms that can be organised within an accounting framework to support analysis and monitoring. The organisation of physical information is the focus of Chapters 2, 3 and 4. Approaches to accounting for ecosystems in monetary terms (Chapters 5 and 6) are also described recognising that this raises additional complexities 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 generally few observable market values for ecosystems and their services.

1.10 The text provides an integrated framework for ecosystem accounting but in a number of areas it is clear that further advancement of concepts and theory are required, and in all areas the development and testing of measurement methods is needed. In recognition, a research agenda for ecosystem accounting is described in Annex I. It is important that on-the-ground experience be gained through the testing of the accounting framework outlined in SEEA

[2] The words "physical terms" are 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, water) but in other cases measures in physical terms refer to non-material flows such as the amenity services from landscapes.

Experimental Ecosystem Accounting. To this end it is expected that the concepts and terminology described here will support testing efforts and facilitate the sharing of experiences in ecosystem accounting.

1.11 In due course, the accounting framework described in this document will be reviewed in light of country experience as well as conceptual advances, and updated to further support collaboration across disciplines and countries to develop and use ecosystem accounts.

Motivation for SEEA Experimental Ecosystem Accounting

1.12 The development of SEEA Experimental Ecosystem Accounting stems from 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 measurement of the environment and the economy as described in the SEEA Central Framework and the System of National Accounts (SNA).

1.13 By taking a systems perspective of environmental assets, information organised following 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 between the different mixes of ecosystem services that arise from alternative uses of ecosystems.

1.14 Through its potential to inform on environmental impacts and trade-offs in ecosystem use, SEEA Experimental Ecosystem Accounting responds to growing demands for information in policy areas such as sustainable development, resource use, and land management. The SEEA Central Framework and the SNA can inform on these issues from an economic perspective but the complementary perspective provided by SEEA Experimental Ecosystem Accounting is 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 43rd meeting in February 2012, the UNSC adopted the SEEA Central Framework as an initial international statistical standard for environmental-economic accounting. The SEEA Central Framework is a multi-purpose, conceptual framework that describes interactions between the economy and the environment, and the stocks and changes in stocks of environmental assets. It provides a structure to compare and contrast source data and allows the development of aggregates and indicators, and analysis of trends across a broad spectrum of environmental and economic issues.

1.16 The SEEA revision process also envisaged the drafting of two additional documents, one covering those topics for which consensus could not be reached but were highly policy relevant, and the other covering applications and extensions of the SEEA Central Framework.

During the drafting of 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 an internationally agreed standard primarily related to accounting for ecosystems and their degradation.

1.17 Recognising the increasing relevance and interest in the measurement of ecosystems, their degradation, and the flow of ecosystem services, UNSC supported the development of SEEA Experimental Ecosystem Accounting, the process being managed through the United Nations Committee of Experts on Environmental-Economic Accounting (UNCEEA). SEEA Experimental Ecosystem Accounting does not constitute an international statistical standard but rather it provides an accounting framework for multi-disciplinary research and testing on ecosystems and their relationship to economic and other human activity.

Relationship to the SEEA Central Framework

1.18 The accounting framework described in SEEA Experimental Ecosystem Accounting complements the accounting for stocks and flows of environmental assets presented in the SEEA Central Framework. Like the SEEA Central Framework, SEEA Experimental Ecosystem Accounting describes accounting in physical (i.e. non-monetary) terms and monetary terms. The extension in the SEEA to encompass accounting of stocks and flows in physical terms is significant and, in particular, requires the integration of scientific information within standard economic accounting frameworks. A key feature of the SEEA is that the organisation of information in physical terms facilitates comparison to economic data and thus adds to analysis from both economic and environmental perspectives.

1.19 The distinctive perspective in SEEA Experimental Ecosystem Accounting concerns 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 comprising the bio-physical environment, that may provide benefits to humanity.”[3] However, for measurement purposes, environmental assets are considered from two complementary perspectives.[4] In the SEEA Central Framework environmental assets are measured from the perspective of “individual” environmental assets, such as timber resources, land, mineral and energy resources, and water resources.

1.20 In contrast, SEEA Experimental Ecosystem Accounting measures environmental assets from the perspective of ecosystems and, in effect, 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.[5] Ecosystem assets are thus environmental assets seen 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 4, the practice of measuring ecosystem condition is likely to benefit from the use of information contained in the asset accounts for individual resources, such as water and timber

[3] SEEA Central Framework, 2.17
[4] See SEEA Central Framework 2.16 – 2.23.
[5] This dual perspective on environmental assets is introduced in the SEEA Central Framework (2.17-2.22)

resources, that are described in the SEEA-Central Framework.

Relationship to the System of National Accounts (SNA)

1.22 As for the accounting described in the SEEA Central Framework, the ecosystem accounting described in SEEA Experimental Ecosystem Accounting has its genesis in the System of National Accounts (SNA). The SNA is the international statistical standard for the compilation of national accounts which incorporates many of the most commonly considered 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 was finalised in 1953 and the latest standard was released in 2008.

1.23 One motivation for the SEEA is 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 providing an extension to 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 in 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 is recognised as contributing to human well-being. This is achieved by accounting for ecosystem services beyond those that provide input to the production of goods and services that are traditionally within scope of the SNA production boundary. Second, the asset boundary is extended compared to the SNA through (i) using the whole bio-physical environment as a starting point (as done in the SEEA Central Framework); and (ii) recognising a broader set of services from ecosystem assets.

1.26 In making these changes it is necessary to apply the ecosystem accounting approach within the SNA measurement boundaries as well as beyond them to provide a consistent accounting treatment. Hence, understanding and making explicit relevant stocks and flows within the SNA is an important aspect of ecosystem accounting.

1.27 A final area of extension relative to the SNA concerns the focus on smaller spatial areas than is commonly the focus on national accounting. The SNA defines its geographic scope in reference to a countries economic territory. For ecosystem accounting purposes, the economic territory is disaggregated into spatial units following a model described in section 2.3. These spatial units form a focus for ecosystem accounting performing a similar role to economic units (such as enterprises, households and governments) in national accounting.

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 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.[6] Estimation in monetary terms may be sought for other reasons as well including the assessment of alternative policy scenarios and measurement of the social benefits of ecosystem services.

1.29 While measures in monetary terms may be important for some purposes, there is significant advantage in applying accounting approaches to the organisation of information and the compilation of accounts in physical terms, as shown in the SEEA Central Framework.[7] Consequently, the potential of ecosystem accounting as described in SEEA Experimental Ecosystem Accounting is not restricted by a requirement for valuation of ecosystem assets and ecosystem services or by an ambition to derive degradation adjusted measures of national income.

1.30 The broad scope of ecosystem accounting recognises 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 in the organisation of data for assessing changes in ecosystems and the services they provide, and placing the relevant information in a socio-economic context.

1.32 As such, the policy relevance of ecosystem accounting for economic and environmental assessments is very broad and real. It stems from the understanding that policy responses should recognise the fundamental connections between economic activity and ecosystems and hence there are 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 and sustainable development, is being considered in a more integrated, multi-disciplinary fashion with economic, social and environmental factors being assessed jointly in determining appropriate policy responses.

1.33 A general motivation is that ecosystem accounting can provide information for tracking changes in ecosystems and linking those changes to economic and other human activity. A particular motivation for the development of ecosystem accounting stems from the concern that economic and other human activity is leading to an overall degradation of ecosystems and, consequently, there is a reduced capacity for ecosystems to continue to provide the services that people are dependent on.

1.34 This phenomenon is recognised in several global policy processes most notably the ongoing work following Rio +20 and the recent outcomes from the United Nations Convention on Biological Diversity. In addition, global initiatives such as the World Bank's Wealth Accounting and Valuation of Ecosystem Services (WAVES) project and The Economics of Ecosystems and Biodiversity (TEEB) are among key users of ecosystem accounting

[6] 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 Chapter 6.
[7] The SEEA Central Framework outlines physical accounts for flows of energy, water and various residual flows and also describes accounting for stocks of individual environmental assets in physical terms.

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 alternative patterns of production, consumption and accumulation; alternative sources of energy and other resources and the extent of decoupling of 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 that arise from alternative uses of ecosystems.

1.36 The potential to assess trade-offs between baskets of ecosystem services is likely to be a particularly powerful application of the ecosystem accounting framework. This potential arises from (i) the broad scope that includes ecosystem services that contribute to current measures of economic activity as well as other ecosystem services, (ii) the connections in the framework made between ecosystem services and changes in ecosystems themselves (e.g due to ecosystem degradation), and (iii) 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 conceptualised 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 quantity and quality of broad measures of capital are generally recognised as an important element in the assessment of sustainable development and overall human well-being.

1.38 Since ecosystem accounting requires the development of datasets pertaining to specific geo-spatial areas it can provide information for the assessment of integrated policy responses at that level of detail, for example in 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 to build information sets for use in assessing global ecological cycles and the related global economic challenges. Two examples in this area relate to carbon and biodiversity. Recognising that stocks and flows of carbon and changes in biodiversity are central elements in understanding the operation of ecosystems, ecosystem accounting may assist in providing a coherent measurement basis for these two policy areas.

1.3 Objectives and challenges in ecosystem accounting

Accounting objectives

1.40 As outlined in the previous section, the over-arching objective of developing an accounting structure is the integration of environmental and economic information to inform policy discussion. Within this, the more specific objectives in establishing an accounting structure are:

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

(ii) Applying a common, coherent and integrated set of concepts, classifications and terminology thus providing a platform for co-ordination, research and testing

(iii) Allowing connections to be made to environmental-economic information compiled following the SEEA Central Framework thus aiding the understanding of the contribution of ecosystem services to economic production, consumption and accumulation, the attribution of the degradation, restoration and enhancement of ecosystems to economic units, and the development of more comprehensive measures of national wealth

(iv) Identifying information gaps and key information requirements.

1.41 In order to meet the various accounting objectives, there are specific measurement considerations that are discussed in SEEA-Experimental Ecosystem Accounting. The conceptual and methodological responses to them are at different stages of development. The key considerations are:

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

(ii) Spatial areas for the assessment of ecosystem assets need to be delineated;

(iii) The structure of relevant accounts needs to be outlined including links to the SEEA Central Framework accounts; and

(iv) Relevant valuation concepts and techniques need to be described and placed in the context of SNA valuation principles.

1.42 These objectives and consideration 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. SEEA Applications and Extensions Chapter 4 describes some possibilities for the integration of social information within the SEEA framework, noting that the spatial focus of SEEA Experimental Ecosystem Accounting provides an additional avenue by which to consider this integration.

Measurement challenges

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

1.44 These measurement challenges however, do not 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 Due to ecosystem accounting’s measurement focus on spatial areas, a significant opportunity exists to take advantage of emerging geo-spatial datasets and related analytical techniques.

1.46 Central to the success in meeting these various accounting objectives is the involvement of a wide-range of professional communities, most notably natural scientists, economists, social scientists, and official statisticians. While all of these communities come from different perspectives, each group has 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 organisations that are likely to be involved include national statistical offices (NSO); government scientific and meteorological agencies; departments of environment, agriculture, forestry and fishing; and government geographical and geo-spatial information agencies. The establishment of appropriate institutional co-ordination and management arrangements is essential for sustained implementation.

1.48 It is also recognised that ongoing co-ordination with key policy agencies including ministries of finance, planning and environment is essential to ensure that the outputs from the compilation of ecosystem accounts are relevant to the policy questions and monitoring requirements of 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 standardising 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 Thus stepwise and incremental approaches towards ecosystem accounting by targeting specific areas or types of ecosystem service 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, its foundation in ecosystem science, economics, and national accounts is strong. Research in these fields continues to deal with the ever increasing complexity of economic activity and our ever increasing understanding of the world in which we live. At the same time there are some core understandings of ecosystem science, economics and national accounts that are accepted and hence form a base for ecosystem accounting.

Core principles of ecosystem science

1.52 Ecosystems are a "dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit"[8]. The operation of ecosystems involves ecosystem 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 changes from disturbance and succession. The principles of ecosystem management suggest that rather than managing individual species, natural resources should be managed at the level of the ecosystem itself.

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 ecosystem services depends on the area covered by an ecosystem (its extent), and the condition of the ecosystem (its quality). This capacity is modified through human behaviour both positively and negatively. Commonly, through land use conversion (for example forests converted to cropland), certain types of ecosystems are modified or replaced leading 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, the presence of multiple steady states, irreversible change or stochastic (random) behaviour. Many types of ecosystems are influenced, and often dominated by complex dynamics, including temperate and tropical forests, rangelands, estuaries, and coral reefs. 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 manner of human activities from industrial activity, to financial markets, to the behaviour of consumers. In general terms, economics is the study of the choices consumers, business managers and government officials make to attain their goals, given their scarce 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

[8] Article 2 Use of Terms, Convention on Biological Diversity, 2003

economics may have a direct interest in ecosystem accounting and can offer 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.[9]

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 are common areas of focus for economists – noting that there are many more issues to which economics has been applied.

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 resource questions with a focus on sustainable use of non-renewable and renewable resources. Insight into sustainability of policies is obtained by blending economic theory with models and findings from the natural sciences.

1.59 Environmental economics is largely focused on research that can contribute to resolve issues of market failure. Market failures of particular interest are related to externalities, common property and public goods. Two main approaches within environmental economics are the establishment of markets and the identification of missing prices.

1.60 Ecological economics has worked directly on the integration of economic and ecological principles. Ecological economics is a field of research that crosses a number of traditional disciplines and 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 sub-system within the ecosystem and consequently it has an interest in the preservation of 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 conceptualisation 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 services flows, the potential for ecosystems to continue to provide services into the future becomes a direct point of analysis. Such 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 to assess broader social costs and benefits of different policy choices. A broad and expanding set of approaches exist to undertake valuation of these often unpriced services.

Core principles of national accounts

1.63 At the heart of national accounting is the ambition to record, at a national, economy-wide level, measures of economic activity and associated stocks and changes in stocks of economic

[9] While these labels exist, it should be recognised that the boundaries between these fields in practical research are often quite fluid.

assets. The accounting approaches are described at length in the SNA. The SNA provides the conceptual underpinnings of the SEEA Central Framework and SEEA Experimental Ecosystem Accounting.

1.64 Following the SNA, economic activity is defined by the activities of production, consumption and accumulation. Measurement of each of these activities over an accounting period (commonly one year) is undertaken within the constraint of a production boundary that defines the scope of the goods and services considered to be produced and consumed.[10] Accumulation of these goods and services in the form of economic assets (for example, through the construction of a house) is recorded in cases where production and consumption is spread out over more than one accounting period. Further, non-produced and financial assets may be accumulated (for example, through the purchase of land). At its core, national accounts is the reporting of flows relating to production, consumption and accumulation, and stocks of economic assets.

1.65 Central to the measurement of economic activity and economic assets is the recognition of economic units – i.e. the different legal and social entities that participate in economic activity. At the broadest level these entities are categorised 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 in that territory.

1.66 The national accounts thus aim to organise 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. However, the main distinctions are that (i) national accounting 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 (ii) national accounting operates at a far larger scale in providing information for a country and encompassing a wide variety of types of economic units that play quite distinct roles in an economy.

Creating linkages between disciplines

1.68 Placing ecosystems in a national accounting context requires these disciplines to consider measurement in new ways. For ecologists, this requires creating clear distinctions between ecosystem assets and service flows within an ecosystem and to differentiate between those aspects of ecosystems that provide direct benefits to economic and other human activity and those aspects of ecosystems that, effectively, support the provision of these benefits.

1.69 For national accountants, it is necessary 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 see the ecosystem as a complex, self-regulating system that, while influenced by economic activity, also operates outside of the markets and property rights that traditionally define the measurement boundaries of the national accounts.

[10] This boundary also defines the measurement scope for the most widely known national accounts aggregate, Gross Domestic Product (GDP).

1.70 For economists, it is necessary to consider their conceptual models concerning the links between ecosystems and the economy in a strict accounting sense, 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 recognise the significance of systems and the mass of relationships that comprise their fields of interest. Ultimately, it is the aim of SEEA Experimental Ecosystem Accounting to present a system-based approach to recording the relationships between ecosystems, the economy and society that is useful for public policy making and environmental management.

1.5 The role of national statistical offices

1.72 There are a number of aspects of ecosystem accounting as described in SEEA Experimental Ecosystem Accounting that warrant the involvement of national statistical offices (NSO). The actual role an individual NSO might play will depend on the scope of its traditional activities. For example, some NSO have strong traditions in working with geo-spatial data, and others have a history of development and research. NSO with these types of experience may be able to play leading roles in the development of ecosystem accounting.

1.73 Those NSO without this experience may still play an important role. Government agencies leading ecosystem accounting research are encouraged to utilise the expertise of NSO in the following areas that are common roles played by all statistical offices.

1.74 First, as organisations that work with large and various datasets, NSO are well placed to contribute their expertise in the collection and organisation of data from a range of different sources.

1.75 Second, a core part of the role of NSO is the establishment and maintenance of relevant definitions of concepts and classifications. The area of ecosystem accounting has many examples of similar concepts being defined differently and there are known to be multiple classifications of ecosystem services and ecosystem types. In many cases each new study develops its own concepts and classifications. The SEEA Experimental Ecosystem Accounting is a first attempt to give stronger guidance in this important measurement discipline and the ongoing involvement by NSO in this area of work would be beneficial.

1.76 Third, beyond the organisation of information, NSO have capabilities to integrate data from various sources to build coherent pictures of relevant concepts. Most commonly NSO focus on providing coherent pictures in relation to socio-economic information and this capability can extend to environmental information. Given the multi-disciplinary nature of ecosystem accounting data integration is an important requirement.

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

1.78 Fifth, NSO have a national coverage. The focus of the SEEA Experimental Ecosystem Accounting is on the provision of information that permits analysis at the national level rather than more commonly available site or ecosystem specific information. Creating national economic and social pictures is a relatively unique role undertaken by NSO and incorporates an implicit understanding of scaling data. Ecosystem accounting could benefit substantially from consideration of how standard statistical techniques used for official statistics may be applied, in particular in the context of geo-spatial statistics.

1.79 Sixth, NSO can present an authoritative voice by virtue of the application of standard measurement approaches, data quality frameworks and their relatively unique role within government.

1.80 A large number of NSO are also involved in the compilation of national accounts. The application of national accounting expertise will be very 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 from the standard national accounts. Of particular importance will be understanding those aspects of ecosystem accounting that may be implicitly recorded in the standard national accounts – for example as part of measures of agriculture production and the value of land.

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

1.6 Structure of SEEA Experimental Ecosystem Accounting

1.82 Chapter 2 "Principles of ecosystem accounting" presents the accounting model for ecosystems operation that underpins the ecosystem accounting framework and places the model in the context of ecosystems, ecosystem services, and ecosystem assets. These various parts of the model are subsequently described in greater detail in later chapters. Chapter 2 also presents a model of statistical areas that can form a basis for ecosystem accounting, and discusses some general measurement issues that apply to all areas of ecosystem accounting.

1.83 Chapter 3 "Accounting for ecosystem services in physical terms" discusses the measurement of ecosystem services highlighting key issues of scope and coverage, presenting a common classification of ecosystem services, proposing basic accounting structures for recording flows of ecosystem services, and describing general issues in the measuring of the various types of ecosystem service. An annex contains a range of examples of the measurement of ecosystem services in physical terms.

1.84 Chapter 4 "Accounting for ecosystem assets in physical terms" considers measures of ecosystem extent, condition, and expected ecosystem service flows. It explains approaches to the measurement of ecosystem assets, the organisation 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 4 also highlights some specific areas of accounting, namely carbon accounting and accounting for biodiversity, and the relationship of these specific areas to ecosystem accounting.

1.85 Chapter 5 "Approaches to valuation for ecosystem accounting" introduces the general concepts of value that may be utilised 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 for valuation of ecosystem services and discusses their consistency with the valuation concepts and principles. The chapter also considers a range of measurement issues including aggregation and scaling estimates for ecosystem services and ecosystem assets.

1.86 Chapter 6 “Accounting for ecosystems in monetary terms” introduces how estimates of ecosystem services, ecosystem assets and ecosystem degradation in monetary terms can be integrated with information in the traditional national accounts. This chapter also highlights the way in which standard monetary transactions associated with ecosystems can be recognised and recorded, with particular mention of the treatment of payments for ecosystem services.

1.87 These six chapters are supported by a number of annexes to the chapters. The annexes cover approaches to measuring ecosystem services, accounting for carbon and biodiversity, and possible models for a sequence of accounts. An annotated glossary has been included that defines relevant terms and notes alternative terms that are commonly used, and a structured list of references has been provided.

1.88 An annex describes a proposed research agenda for ecosystem accounting focusing on those areas that are considered in most need of further investigation in order to advance ecosystem accounting as a whole. It is expected that the investigation of the issues on the research agenda is undertaken in joint fashion across disciplines and in conjunction with ongoing research and testing programs.

II: Principles of ecosystem accounting

2.1 An overview of ecosystems and biodiversity

Ecosystems

2.1 "Ecosystems are a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit."[11] They change as a result of natural processes (e.g. succession, natural disturbances such as a storm) or because of human actions - either through deliberate management or through human disturbances such as the extraction of natural resources, the introduction of invasive exotic species, or pollution.

2.2 Traditionally, ecosystems have been associated with more or less 'natural' systems, i.e. systems with only a limited degree of 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 dominate 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 a greenhouse or in intensive aquaculture ponds, ecosystem processes have become 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 their key characteristics. Ecosystem characteristics relate to the ongoing operation of the ecosystem and its location. Key characteristics of the operation of an ecosystem are (i) its structure (e.g. the food web within the ecosystem); (ii) its composition, including living (e.g. flora, fauna and micro-organisms) and non-living (e.g. mineral soil, air, sunshine and water) components; (iii) its processes (e.g. photosynthesis, decomposition), and (iv) its functions (e.g. recycling of nutrients in an ecosystem, primary productivity). Key characteristics of its location are (i) its extent; (ii) its configuration (i.e. the way in which the various components are arranged and organised within the ecosystem); (iii) the landscape forms (e.g. mountain regions, coastal areas) within which the ecosystem is located; and (iv) the climate and associated seasonal patterns. Ecosystems also relate strongly to 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 as an ecosystem, as may a tundra ecosystem stretching over millions of hectares. In addition, ecosystems are interconnected, commonly being nested and overlapping, and 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 on ecosystem types more broadly.

[11] Convention on Biological Diversity (2003), Article 2, Use of Terms.

2.6 It is widely recognised that ecosystems are subject to complex dynamics. The propensity of ecosystems to withstand pressure 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, due to ecosystem degradation (e.g. 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 understanding of these 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 ecosystems'[12]. The scientific community has conceptualised biodiversity as a hierarchy of genes, species and ecosystems.

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

2.9 At the ecosystem level, biodiversity loss is characterised 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 occurring in a particular area will decrease in abundance while at the same time some species, in particular those that benefit in disturbed habitats, increase in abundance, as a result of human interventions. 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 extinctions of the endemic species are 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 exotic species introduced or favoured by humans[13]. Because of these changes ecosystems lose their regional endemic species and become more and more alike – a process described as "homogenisation"[14].

[12] Convention on Biological Diversity, Article 2, Use of Terms.
[13] This is the so-called "intermediate disturbance diversity peak", Lockwood and McKinney, (2001). Biotic Homogenization. Kluwer, New York. 289p.
[14] Lockwood and McKinney, (2001). Biotic Homogenization. Kluwer, New York. 289p and Millennium Ecosystem Assessment (2005). http://www.maweb.org/en/Reports.aspx

2.11 The interconnected nature of biodiversity and ecosystems is reflected in the reality that biodiversity is a fundamental characteristic of ecosystems, while at the same time variability among ecosystems is a fundamental driver of biodiversity. There are therefore also important links between biodiversity, ecosystems and resilience that 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 comprising an *ecosystem asset*.[15] Each ecosystem asset has a range of *ecosystem characteristics* – such as land cover, biodiversity, soil type, altitude and slope, climate etc – 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 are more variable (e.g. rainfall, land cover and biodiversity).

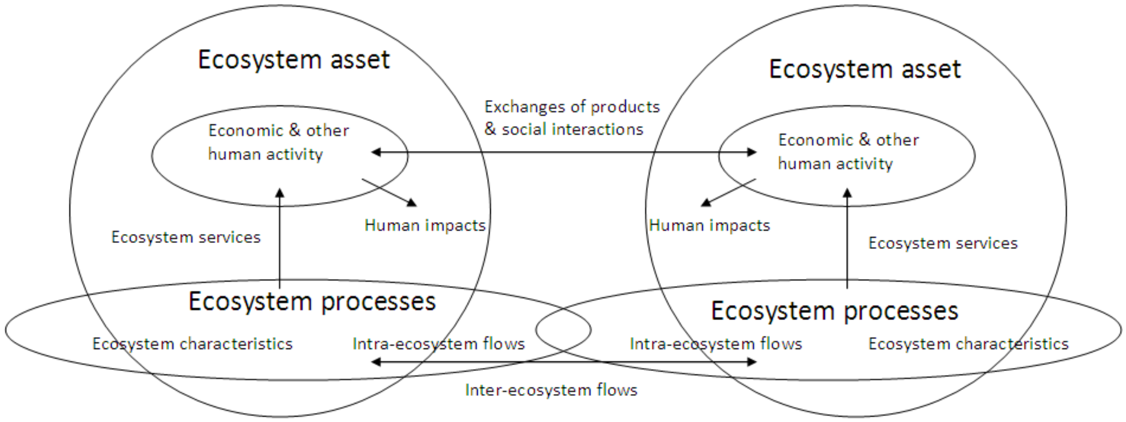
2.13 The flows in ecosystem accounting are of two types. First, there are flows within and between ecosystem assets that reflect ongoing ecosystem processes – these are referred to as *intra-ecosystem flows* and *inter-ecosystem flows.* The recognition of inter-ecosystem flows highlights the dependencies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

2.14 Second, there are flows reflecting that people, through economic and other human activity, take advantage of the multitude of resources and processes that are generated by ecosystem assets – collectively these flows are known as *ecosystem services.* Ecosystem services are generated through ecosystem processes that reflect the combination of ecosystem characteristics, intra-ecosystem flows and inter-ecosystem flows. It is noted that flows of ecosystem services may relate to either flows of inputs from the environment to the economy (e.g. from the logging of timber resources) or flows of residuals to the environment (e.g. emissions, waste) from economic and other human activity. Flows of both 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 of 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 recognises the strong spatial relationship between ecosystems and economic and other human activity. The model also recognises the strong connections between different ecosystem assets in terms of ecosystem processes, exchanges of economic products, the ecosystem impacts of economic and other human activity, and other social interactions (e.g. the movement of people) that cross spatial boundaries.

[15] The relationship between ecosystem assets and environmental assets as defined in the SEEA Central Framework is described in Section 2.6.

Figure 2.1 Basic model of ecosystem stocks and flows



2.16 From a measurement perspective, ecosystem accounting focuses (i) on the flows of ecosystem services to enable improved understanding of the relationship between ecosystems and economic and other human activity; and (ii) on 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 that reflect the effect of these processes on ecosystem assets and ecosystem services. Therefore, the nature of these flows needs to be understood conceptually to explain the relevant relationships.

2.17 This basic model of ecosystem stocks and flows reflects one view of the physical relationships that are present within and between ecosystems. In practice, the relationships are far more complex than depicted in Figure 2.1. However, since the model is described in terms of stocks and flows, the model can also be applied in the context of measuring the relationships in monetary terms. This dual, physical and monetary, application of the model lies at the heart of the ecosystem accounting described here to provide coherent and integrated information about the relationship between ecosystems and economic and other human activity.

2.18 The remainder of this sub-section provides 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 the following chapters.

2.2.1 Ecosystem services

A model for ecosystem services[16]

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 used and enjoyed by people on the other. Hence they are at the intersection of the relationship between ecosystems and

[16] The model of ecosystem services developed for SEEA Experimental Ecosystem Accounting is based on a large literature related to this topic. A structured list of references is included as an annex.

economic and other human activity which is the focus of the environmental-economic accounting described in the SEEA.

2.20 A range of definitions and interpretations of ecosystem services have been used in various contexts 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 at *individual and societal well-being*, the chained approach recognises that well-being is influenced by the receipt of *benefits*.[17] In the context of ecosystem accounting, benefits comprise

(i) The products produced by economic units (e.g. food, water, clothing, shelter, recreation, etc). 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.[18]

(ii) 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 that the receipt of these benefits by individuals is not the result of an economic production process defined within the SNA. A distinguishing characteristic between these two types of benefits is that, in general, SNA benefits can be bought and sold on markets whereas non-SNA benefits cannot.

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

2.23 In SEEA Experimental Ecosystem Accounting, ***ecosystem services are the contributions of ecosystems to benefits used in economic and other human activity***.[19] 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, commonly referred to as supporting services. While these flows are not considered ecosystem services, they are considered as part of the measurement of ecosystem assets.

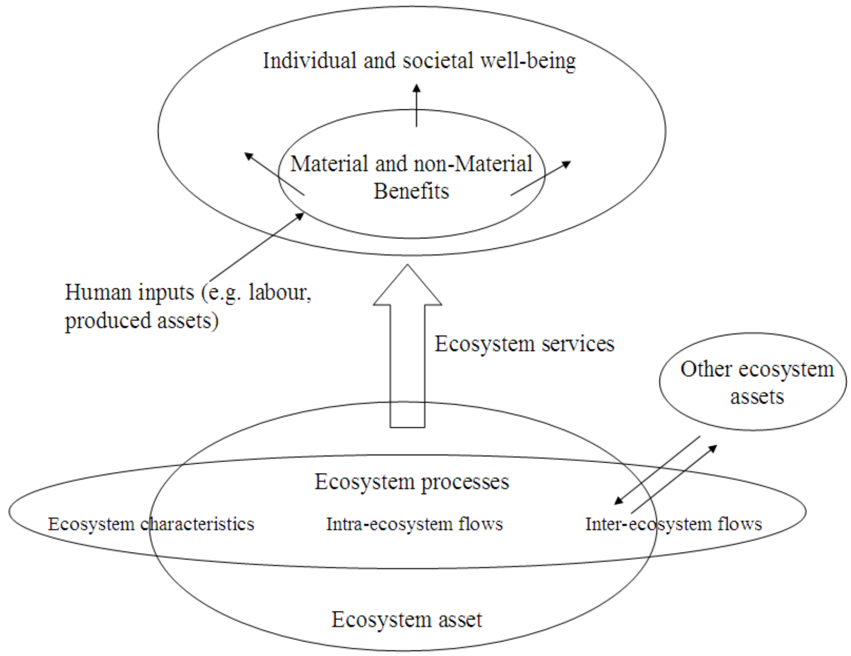
2.24 The model of ecosystem services takes no explicit account of so-called ecosystem "disservices" such as pests and disease. To some extent these flows will be reflected in reduced flows of some ecosystem services (e.g. lower flows of provisioning services). Chapter 3 discusses this issue further.

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

[18] 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 child care (with the exception that housing services produced through ownership of dwellings are included).

[19] 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. amenity from viewing landscapes).

Figure 2.2 Stylised model of flows related to ecosystem services



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

2.26 For non-SNA benefits there are usually few human inputs in their generation and 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 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 do not result only from the harvesting or extraction of materials from ecosystems. They also result from the general functioning of the ecosystem (e.g. air filtration services from trees providing clean air) and to other characteristics of an ecosystem (e.g. the physical structure and composition of mountain landscapes providing wonderful views). Thus the term "services" is used here in an all-encompassing manner covering the various ways in which humans may benefit from ecosystems.

2.28 Ecosystem services do not represent the complete set of flows from the environment. Important examples of other environmental flows include the extraction of mineral and energy resources, energy from the sun for the growing of crops and as a renewable source of energy, and the movement of wind and tides, which can be captured to provide 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 conceptualised as an environmental flow. Collectively, these other environmental flows are referred to as *abiotic services*. The relevant boundary issues are discussed further in Chapter 3.

2.29 The final step in the series of flows related to ecosystem services is the recognition that ecosystems do not function only to generate ecosystem services. Many intra- and inter-ecosystem flows do not benefit humans directly but they support the functioning and resilience of ecosystems which in turn makes it possible to generate final ecosystem services now and in the future. Therefore, the multitude of ecosystem flows and characteristics that constitute a functioning ecosystem are of relevance and can be captured by accounting for ecosystem assets.

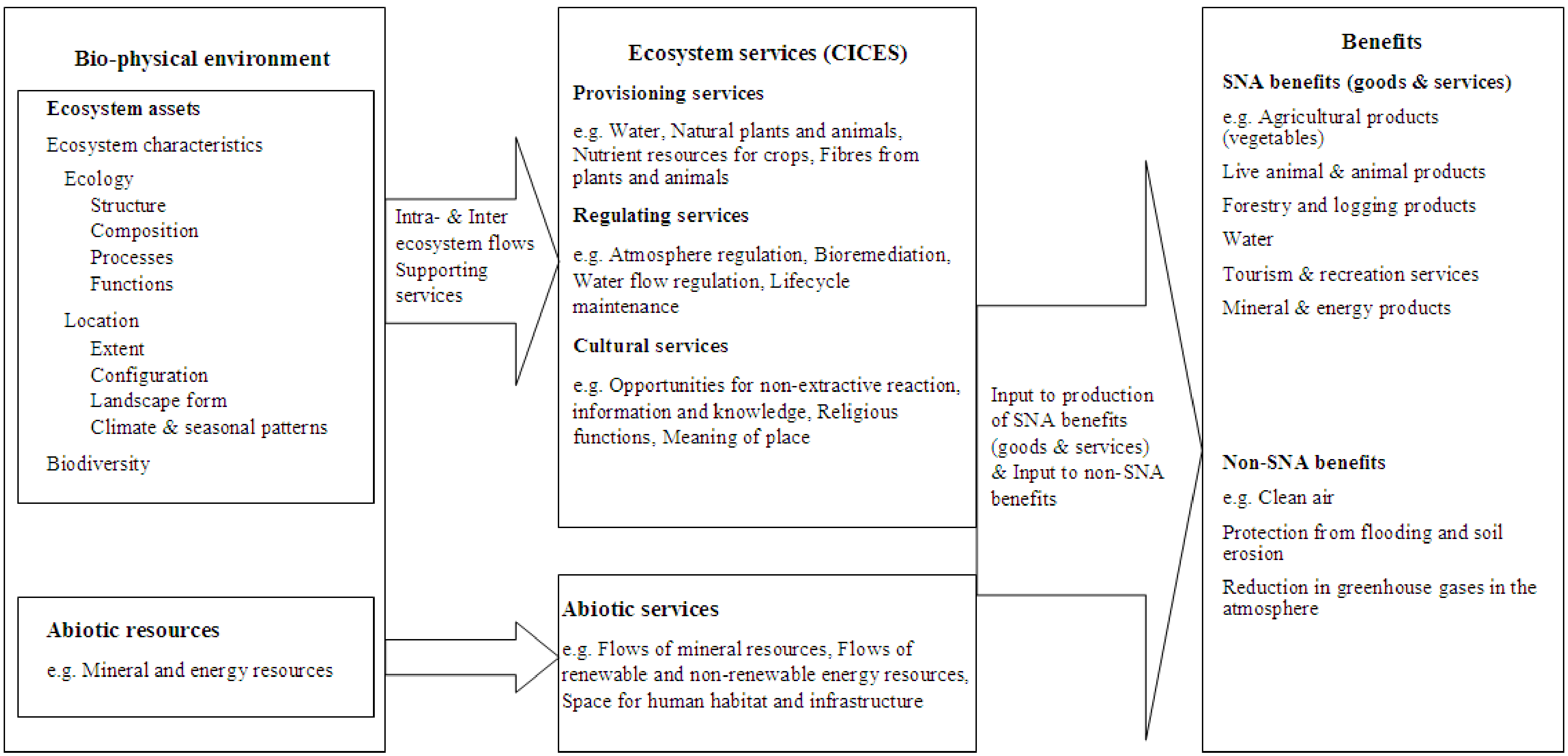
2.30 One way of reflecting the relationships between ecosystem services and the other relevant measures concerning ecosystems is presented in Figure 2.3. This figure places ecosystem services in the context of the bio-physical environment, ecosystem assets, ecosystem processes, ecosystem characteristics, 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 3 provides more detail regarding the relevant measurement boundaries that need to be defined to ensure appropriate accounting for ecosystem services.

2.2.2 Central concepts in measuring ecosystem assets

2.31 ***Ecosystem assets are spatial areas containing a combination of biotic and abiotic components and other characteristics that function together.*** Ecosystem assets are measured from two perspectives. First, ecosystem assets are considered in terms of *ecosystem condition* and *ecosystem extent*. Second, ecosystem assets are considered in terms 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, at a point in time, an estimated stock of *expected ecosystem service flows.*

2.32 In general terms, the capacity of an ecosystem asset reflects the relationship between the characteristics of the asset and the expected uses of the ecosystem asset (described 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 the capacity of the ecosystem asset to generate those services. In the context of a single resource, for example timber resources, 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 that may be produced in tandem or in competition, will be quite complex. Since ecosystem services are only recorded when there are associated benefits to economic or other human activity, there is no notion of "unused" ecosystem services arising if an ecosystem asset is considered to be generating ecosystem services below its capacity.

Figure 2.3 Broad model of flows in ecosystem accounting



2.33 The capacity of an ecosystem asset should be distinguished from the potential of an ecosystem asset 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 assessments 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 two perspectives of ecosystem assets is not simple, and it is likely to be non-linear and variable over time. As a result of this complexity, there is incomplete knowledge of the relationships between ecosystem extent and condition and future flows of ecosystem services, although it is an active area of ecological research. For ecosystem accounting, a variety of measures of ecosystem assets is needed and it cannot be assumed that measurement from one perspective will be able to provide a comprehensive assessment of ecosystem assets. Through a measurement focus on well-defined spatial areas (see Section 2.4) these two perspectives can be integrated to provide a more complete picture of ecosystem assets and the changes in them.

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 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 made on scientific basis such that there is assessment of the ongoing functioning, resilience 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.

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. for agriculture, forestry, carbon sequestration, recreation, etc) 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. There will not usually 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. A number of conceptual alternatives to determine a reference condition are described in Chapter 4. The use of a common reference condition for all indicators for an ecosystem asset may allow an overall assessment of the condition of the ecosystem 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, e.g. hectares of a land cover type.[20] Where there is a mix of land covers within an ecosystem asset (e.g. within 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 mix 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 individual ecosystem assets are likely to provide a useful indicator of changes in the condition of that ecosystem 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 in effects on species abundance and richness. The potential to undertake accounting for biodiversity at the species level is discussed in detail in Section 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.***[21] The expected flows must be based on an expected basket of provisioning, regulating and cultural services from an ecosystem 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 expectations on the amount of extraction and the amount of regeneration that will take place, and on the overall sustainability of human activity in the ecosystem. To form these expectations information concerning likely changes in ecosystem condition is required, noting that a basic assumption is that the flows of the relevant ecosystem services are constant.

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

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

[21] 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 an asset is expected to deliver over its lifetime.

Changes in ecosystem assets

2.43 Measures of ecosystem condition and extent, and measures of expected ecosystem service flows are all aggregate or 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 which reflect the different 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 changes in ecosystem extent, commonly reflected in changes in land cover. Changes in ecosystem condition and expected ecosystem services flows (calculated as differences between beginning and end of period stocks) 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 and attributing the changes over an accounting period to various causes. In the context of ecosystem accounting there is interest in changes due economic and other human activity as distinct from natural causes, and changes due to extraction 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 4.

2.3 Units for ecosystem accounting

2.3.1 Introduction

2.46 In order to undertake measurement of ecosystems in a co-ordinated way and to subsequently compare and analyse information across time and between ecosystems, there must be a clear focus for measurement. For accounting purposes, it is necessary to have well defined boundaries that can be applied at specific scales of analysis and which are suitable for the organisation 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 in terms of having stronger internal functional relations than external ones. However, these boundaries are often gradual and diffuse and a definitive boundary between two ecosystems may be difficult to establish. Further, ecosystems may be very small or very large and 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 compilation of statistical aggregates and to which tabulated data refer.[22] 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.[23]

[22] Statistical units should be distinguished from units of measurement, such as money, tonnes, hectares, that provide a common basis for the recording of specific variables.

[23] See Glossary for more detailed definitions of relevant terms. An overview of economic units is provided in the SEEA Central Framework (Chapter 2) and complete descriptions of economic units from the perspective of national accounting are provided in SNA Chapter 4.

Economic units may be grouped for analytical purposes into industries (units undertaking similar economic activities) and 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. Examples of methods include remote sensing, on-ground assessment, surveys of land owners and administrative data.

2.50 To accommodate the different scales and methods used to collect, integrate and analyse data three different, but related, types of units are defined in SEEA Experimental Ecosystem Accounting. They are: basic spatial units (BSU), land cover/ecosystem functional units (LCEU) and ecosystem accounting units (EAU). The following sub-sections describe each type of unit.

2.51 The relationships between the three types of units can either be viewed in a bottom up (i.e. starting with the BSU) or a top down (i.e. starting with EAU) manner. That is, the BSU may be aggregated to form LCEU or EAU, while LCEU or EAU may be disaggregated to form BSU. Direct measurement may be made at each of the levels, depending on the concept being measured.

2.52 The units model described in this section may appear prescriptive but 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 appropriate. The basic 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 (BSU) is a small spatial area. Ideally, the BSU should be formed by delineating tessellations (small areas e.g. 1 km^2), typically by overlaying a grid on a map of the relevant territory, but they may also be land parcels delineated by a cadastre[24] or using remote sensing pixels. Grid squares, ideally each one being 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. a 100 m^2 grid nested within a 1 km^2 grid). It is particularly advantageous for each BSU to refer to the same spatial area over time.

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. For example, relevant information may include 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, land ownership, location relative to human settlement, and the degree of accessibility to the area by people.

[24] 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.

2.55 This information may be extended to include information on the generation of different ecosystem services from the BSU such that the BSU can represent the level at which all relevant information for ecosystem accounting is assimilated and organised. 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 3.

2.56 If possible, information on any associated economic units, for example land owners, should be attributed to each BSU. This range of information recognises that while each BSU is a mutually exclusive area, it can be linked to a number of other spatial areas (e.g. EAU) and that ecosystem assets and ecosystem services may operate at varying spatial scales linking to more than one economic unit. The link to economic units is discussed further in sub-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 an LCEU is defined by areas satisfying a pre-determined set of factors relating to the characteristics of an ecosystem. Examples of these factors include land cover type, water resources, climate, altitude, and soil type. A particular feature is that an LCEU should be able to be consistently differentiated from neighbouring LCEU based on differences in their ecosystem characteristics.

2.58 The resulting LCEU would commonly be considered an ecosystem noting that strictly, ecosystems are not able to be defined purely in spatial terms. LCEU may be disaggregated into BSU (e.g. by overlaying a grid) or BSU may be aggregated to form LCEU (i.e. the LCEU reflects a contiguous set of BSU each having the same core characteristics). Aggregation could take place following standard approaches to statistical classification, with BSU being classified to particular LCEU on the basis of a predominance of 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 BSU 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 classes for land cover/ecosystem functional units showing 15 classes is shown in Table 2.1. The classes are based on the FAO Land Cover Classification System, version 3 (LCCS 3) (FAO, 2009). This approach uses as its starting point the Land Cover Classification presented in the SEEA Central Framework Chapter 5 (which is also based on LCCS 3) and combines these into classes that are optimised for the analysis of changes in land cover and land use. The LCEU classes can be augmented by other characteristics, for example, relating to broad climatic zone (e.g. tropical, sub-tropical and temperate), elevation (e.g. lowlands, highlands) and topography (e.g. plains and mountains).

2.60 LCEU will vary in size depending on the situation in a given country. Also, not all countries will have all types of LCEU (as described in Table 2.1). Various studies and reports (e.g. Convention on Biological Diversity, Millennium Ecosystem Assessment, UK National Ecosystem Assessment) have used different classifications but all using terms that may be considered commonly understood (e.g. forests, wetlands, grasslands, coastal areas).

2.61 At any point in time, all LCEU 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 BSU will need to be re-classified to different LCEU – for example from Agriculture associations and mosaics to Urban and associated developed areas.

2.62 The LCEU defines an area for which accounting may be undertaken and hence LCEU 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 LCEU wherever they are located, e.g. concerning all open woodlands or wetlands in a country or region, and also comparison of different types of LCEU 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 rainfed herbaceous cropland
Medium to large fields irrigated herbaceous cropland
Permanent crops, agriculture plantations
Agriculture associations and mosaics
Pastures 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 LCEU represent the closest approximation to ecosystems in spatial terms given the way that large ecosystems are commonly envisaged. However, in order to more fully adapt LCEU delineation to ecosystems types it is likely to be necessary to allow for variations in climatic conditions, geophysical conditions, and land use. For example, in some countries, "Forest tree cover" may reflect substantial differences in canopy cover of a given area. For some purposes it may be relevant to cross classify LCEU by the extent to which the area is considered influenced by human activity. Thus types of LCEU (e.g. Forest tree cover) may be considered as reflecting natural, semi-natural, agricultural or other types of ecosystems.

2.64 Table 2.1 presents a provisional list of classes for land cover/ecosystem functional units (LCEU). The development of this classification is part of the research and testing agenda.

2.3.4 Ecosystem accounting units

2.65 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 factors relevant to defining areas relevant for reporting purposes (e.g. national parks or other protected areas). Overall, EAU should be relatively large areas about which there is interest in understanding and managing change over time.

Consequently, EAU should be fixed or largely stable spatial areas 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 EAU building from smaller reporting units to the national level. For example, starting from a local administrative unit a hierarchy of EAU may build to provincial and then national level. In all cases, a country's total area will represent the single, highest level in a hierarchical EAU structure.

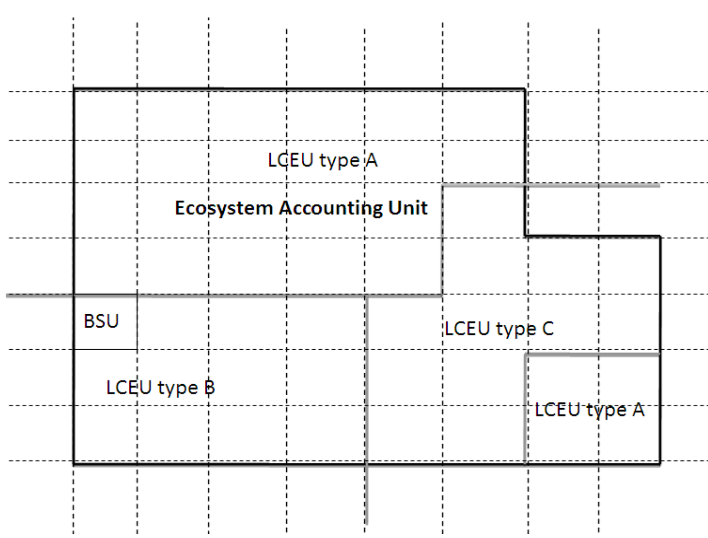
2.67 A specific concept that has been developed that may be useful in the delineation of EAU is socio-ecological systems. Areas defined as socio-ecological systems integrate ecosystem functions and dynamics as well as human activities and the range of interactions of these components.

2.68 For the purposes of national scale ecosystem accounting it is recognised that EAU 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 recognise different hierarchies of EAU. For example, a set of EAU 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 EAU within each set may be aggregated to form national totals but there should not be aggregation of EAU across different sets (e.g. adding 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 stylised depiction of the relationships between BSU, LCEU and EAU where, in this case, the BSU are defined by grid squares. Attribution of BSU to LCEU and to EAU 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 Stylised depiction of relationships between BSU, LCEU and EAU



2.3.5 Spatial units in relation to ecosystem services

2.71 It should be recognised that 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 analogy between the BSU and an establishment in economic statistics that undertakes a single kind of activity.

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

2.73 Although the generation of ecosystem services may take place over varying spatial areas depending on the service, for a broad range of services a useful measurement starting point 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 service generation may be useful tools in delineating LCEU by providing an understanding of concentrations of related ecosystem services, noting that each ecosystem service is likely to have its own specific area over which it is generated. By linking maps of service generation to LCEU delineated by land cover, the relationship between land cover and service generation can be tested experimentally.

2.3.6 Relationship to economic units

2.74 The cross-classification of ecosystem information with economic units is central to 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 such connections to 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 land ownership (via cadastres) within the broader process of delineating BSU or LCEU. If this detailed linking is not possible then broader assumptions may be used for example by attributing information on land use or land ownership to BSU or LCEU.

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

2.77 It is noted that the beneficiaries of the ecosystem services may be the land user or owner, or, it may be people living nearby (as in the case of air filtration) or populations at large (as in the case of carbon sequestration). Further, in specific cases the beneficiaries may be spatially delineated, such 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 hydrological 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 such as soil type and status, water tables, rainfall amount and pattern, temperatures, vegetation, biodiversity, slopes, altitude, etc., as well as, potentially, information on land management and use, population, and social and economic variables. This information may 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 geographic 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 coverage to incorporate marine areas under the control of a national administration. In the context of the SEEA this is deemed 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 that stated scope of the accounts, potentially 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 defining the treatment of coastal ecosystems that straddle terrestrial and marine areas, in the delineation of areas related to rivers, such as flood plains, and the treatment of other linear features, and the definition of aquatic ecosystems such as wetlands. The delineation of marine areas taking into account not only their area but also the operation of ecosystems at varying depths as well as the sea floor is also important.

2.82 Although much relevant research has been completed in relation to these matters the delineation of relevant units and their integration with the terrestrial units described in this section has not been completed from the perspective of ecosystem accounting and this task has been placed on the research agenda. Links to relevant developments are listed in the References annex.

2.4 Ecosystem accounting tables

2.83 To provide a basis for understanding the nature of ecosystem accounting described here, this section describes 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 sense of the potential of ecosystem accounting to organise 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 these tables and possible extensions to them are discussed in Chapters 3 and 4.

2.4.1 Tables for ecosystem services

2.84 Tables for ecosystem services primarily aim to organise 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 analytical objective is to use information on the mixes of ecosystem services within an ecosystem asset (i.e. the observable basket of ecosystem services) to consider what trade-offs may be implied between alternative uses. As well it is this information that can be used to construct scenarios of 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 In this regard it is relevant to note that usually ecosystem services are interconnected. They may be generated in tandem, enhanced by the generation of other ecosystem services or certain ecosystem services 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 various social and ecosystem contexts that may be affecting the reported area.

2.87 Table 2.2 shows a basic table 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. It is noted that 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 3 contains a description of possible extensions of the basic table shown below and approaches to aggregation.

Table 2.2 Physical flows of ecosystem services for an EAU

	Type of LCEU				
	Forest tree cover	Agricultural land*	Urban and associated developed areas	Open Wetlands	…
Type of ecosystem services					
Provisioning services	e.g. tonnes of timber	e.g. tonnes of wheat			
Regulating services	e.g. tonnes of CO_2 stored/released	e.g. tonnes of CO_2 stored/released	e.g. tonnes of CO_2 stored/released	e.g. tonnes of P absorbed	
Cultural services	e.g. number of visitors/hikers		e.g. hectares of parkland	e.g. hectares of duck habitat	

***** Medium to large fields rainfed herbaceous cropland

2.4.2 Tables for ecosystem assets

2.89 Because of the range of concepts involved in the measurement of ecosystem assets a number of tables may be constructed. Tables concerning ecosystem extent largely emerge from the asset accounts for land described in the SEEA Central Framework. Most important are measures of the area of different LCEU that may be developed along the lines explained for land cover accounts (see SEEA Central Framework Section 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, increases in tree cover) and are generally more straightforward to compile than information on more qualitative aspects of ecosystem condition.

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

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

2.93 The table relates to a specific EAU (or for a country as whole) and is structured by type of LCEU noting 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 to provide a basis for assessing changes in overall ecosystem condition. Information on each indicator will be collected using different measurement units but may 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

	Ecosystem extent	**Characteristics of ecosystem condition**				
		Vegetation	Biodiversity	Soil	Water	Carbon
	Area (proportion of EAU)	Indicators (e.g. Leaf area index, biomass index)	Indicators (e.g. species richness, relative abundance)	Indicators (e.g. soil fertility, soil carbon, soil moisture)	Indicators (e.g. river flow, water quality, fish species)	Indicators (e.g. net carbon balance, primary productivity)
Type of LCEU						
Forest tree cover						
Agricultural land*						
Urban and associated developed areas						
Open wetlands						

* Medium to large fields rainfed herbaceous cropland

2.94 Measures of ecosystem condition should cover the main aspects 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 will be informed by ongoing experimentation and testing.

2.95 The ambition for this table is to present indicators of ecosystem extent and condition for each LCEU type. Possible approaches to aggregation and considerations in relation to assessing change in condition are discussed in Chapter 4.

2.96 Table 2.4 presents a basic structure for information on expected ecosystem service flows. As with the measures of ecosystem services shown in Table 2.2, the entries in this table will be in different units 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 remaining timber available over 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 noting 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 will be needed and, at least, close collaboration between compilers and scientists, 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				
	Forest tree cover	Agricultural land*	Urban and associated developed areas	Open Wetlands	…
Type of ecosystem services					
Provisioning services					
Regulating services					
Cultural services					

* Medium to large fields rainfed herbaceous cropland

2.99 A potential extension to Table 2.4 is to relate the expected ecosystem service flows to the various economic units. In this way, assessments of trade-offs between alternative baskets of ecosystem services may be additionally informed by data related to social and economic effects.

2.100 Accounting for changes in ecosystem assets is a complex task, especially in terms of defining and accounting for ecosystem degradation. The relevant issues are discussed in Chapter 4.

2.5 General measurement issues in ecosystem accounting

2.101 This section introduces a number of general measurement issues that may arise in the compilation of ecosystem accounts: (i) the integration of information across different spatial scales, (ii) the transfer of data, (iii) gross and net recording, and (iv) the length of the accounting period. They are primarily practical issues but are important considerations in setting up a framework for ecosystem accounting following the general model outlined 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 and decisions. Consequently, consideration must be given to collecting and collating information pertaining to many ecosystems across a region or country. It is noted that there are other objectives for the organisation of information on ecosystems including the assessment of specific ecosystems or local development projects. In these cases 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 macro-level accounting and long-term monitoring such individual 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 spatial data. The primary sources of the challenges lie in the uncertainty of measurement and the uncertainty of understanding. The four main geospatial analytical problems are known as the scaling problem, the boundary problem, the pattern problem and the modifiable unit area problem. Given the challenges involved the following paragraphs only point to the important considerations from the perspective of ecosystem accounting and geospatial expertise should be involved in the design of the 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 (BSU), land cover ecosystem functional units (LCEU) and ecosystem accounting units (EAU) should provide a comprehensive coverage of areas within a country. The units model provides a basis for integrating information but it may be that different techniques (as introduced below) need 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 assets is relevant in the scaling of data described in the following sub-section.

2.105 The information used to characterise the different units provides important data that may be used to aggregate and disaggregate across units. For example, 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 BSU containing standard information about these units can 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 that is included within it. For example, a few 10ºC bands with similar temperatures may represent average temperature for a country. 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, BSU in higher elevations may be assigned a lower average temperature.
- Overlaying: Network features such as roads and rivers can be attributed to BSU by overlaying maps of these features and recording the length that passes through the BSU. The length of road or river that passes through the BSU 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 the 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 BSU may be used to allocate the wheat production between the two. The effectiveness of these techniques will be enhanced by the availability of core measures such as land cover and locations of households that can be used as a basis of 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 socio-economic data, there is 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 use 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 only at a limited number of locations. Often a large amount of information on ecosystems comes from focused evaluations at individual sites. Therefore, to develop information 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. First, *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 5. Second, *scaling up*, which involves using information from a study site and developing information for a larger area that has similar characteristics. Third, *meta-analysis* which is a technique for assessing a large volume of information on various study sites and integrating the information to provide factors that can be used to estimate information in 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 rigorous geospatial methods before an aggregation of information to regional or national levels takes place. Using such a description of units, the application of the advancing techniques around benefit transfer may be undertaken with greater robustness and in a manner more in line with 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 used to indicate whether an accounting aggregate has been adjusted for consumption of fixed capital (depreciation). In other situations, the term net is used simply to refer to the difference between two accounting items. The terms gross and net are also used to describe different 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 that may arise due to overlaps between areas, overlaps in the use of different methods, and overlaps due to not recognising distinctions 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 the SEEA Experimental Ecosystem Accounting. This is intended to limit the potential for confusion in the use of these terms. At the same time, the general ambition is to describe the relevant concepts in what might be considered “gross” terms such that all assumptions and relationships can be fully articulated. Further, compilers are encouraged to record accounting details in gross terms to as great an extent as possible and then explain any subsequent differencing of accounting entries that is used to generate estimates in net terms that 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 suits many analytical requirements (although often quarterly accounts are also compiled) and also aligns with the availability of data through business accounts.

2.116 While one year may suit analysis of economic trends, analysis of trends in ecosystems may require information of varying lengths of time depending on the processes being considered. Even in situations where ecosystem processes can be analysed on an annual basis, the beginning and end of the year may well differ from the year that is used for economic analysis.[25]

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 to a common annual basis using appropriate factors or assumptions (e.g. by interpolation or extrapolation), recognising 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 assuring 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 Data quality for official statistics is a broad ranging concept that encompasses 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 only one element that needs to be considered in the context of the other elements of data quality. Given the

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[25] For example hydrological years may not align with calendar or financial years (see *International Glossary of Hydrology, 2nd ed*., UNESCO/WMO, 1992).

measurement challenges faced in advancing ecosystem accounting it is important that all elements of data quality be brought into consideration.

2.122 In ecosystem accounting it is likely that a reasonable proportion of the information used will be drawn from disparate data sources, potentially developed primarily to provide administrative information rather than information for statistical purposes.[26] Care must therefore be taken to ensure that, as far as possible, the information can be aligned with appropriate concepts and measurement boundaries.

2.123 It is also likely that information for ecosystem accounting will be drawn from scientific studies. Unlike most information collected for economic statistics, which is collected and analysed in a common metric of money, scientific information often does not have a common metric and consequently assessment of relative quality may be more challenging. In this situation it is important that scientific information undergo processes of peer review and accreditation to ensure that it is fit for the purposes of ecosystem accounting. Such processes should relate to both an assessment of the accuracy of individual indicators and pieces of information and to 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 UN National Quality Assurance Framework, are applicable to biophysical data as well as socio-economic data. These frameworks are tools 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 (i) physical flows between the environment and the economy, (ii) the stocks of environmental assets and changes in these stocks; and (iii) 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).

[26] Administrative data sets are often set up and analysed with a focus on smaller or borderline cases rather than on those cases that may be the most statistically significant. A similar trait applies to some ecological data. For example, water quality data may be collected for areas where there is a known pollution problem rather than being collected to provide a broad coverage and representative sample of water quality.

2.127 It is noted that the production of goods on own-account (for example, the 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.

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. 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 3. It is recommended that information on these flows should be presented alongside information on ecosystem services and ecosystem assets 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 compared to 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 comprising the bio-physical environment, that may provide benefits to humanity"[27] . This scope is broader than the physical asset boundary used in 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 its value.

2.130 This broad scope encompasses two complementary perspectives on environmental assets. The first perspective, which is the focus of the SEEA Central Framework, is of environmental assets in terms of individual resources (e.g. timber, fish, minerals, land, etc). The second perspective, which is the focus of SEEA Experimental Ecosystem Accounting, considers the bio-physical environment through the lens of ecosystems in which the various bio-physical components (including individual resources) are seen to operate together as a functional unit. Thus, ecosystem assets are environmental assets seen 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 these are specific perspectives taken within the same bio-physical environment as defined by environmental assets in the SEEA Central Framework.

2.132 While there is, in principle, no extension in the bio-physical environment, there are some particular boundary issues that warrant consideration, particularly concerning marine ecosystems and the atmosphere. The ocean and the atmosphere are excluded from the measurement scope in 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 the context of statistical units for ecosystem accounting in Section 2.3.

2.133 An important part of the SEEA Central Framework is the definition of depletion of individual natural resources. SEEA Experimental Ecosystem Accounting considers measures of

[27] SEEA Central Framework, 2.17.

depletion within a broader concept of ecosystem degradation. Ecosystem degradation is a measure that covers not only the using up of resources but also the declines in the capacity of ecosystems to generate other ecosystem services (e.g. air filtration).

2.134 Third, the SEEA Central Framework outlines clearly the types of economic activity that are considered environmental and also describes a range of relevant standard economic transactions (such as taxes and subsidies) that are relevant for environmental accounting. It also shows how these flows may be organised in functional accounts – the main example being Environmental Protection Expenditure Accounts.

2.135 For the purposes of ecosystem accounts, there are no additional transactions that are theoretically in scope since the SEEA Central Framework has, in principle, a scope that 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, 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 valuation principles applied in SEEA Experimental Ecosystem Accounting are consistent with 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 these approaches with the concept of exchange value that underpins the 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.

III: Accounting for ecosystem services in physical terms

3.1 Introduction

3.1 Ecosystem services have become a central concept in connecting characteristics of ecosystem assets with the benefits received from ecosystems by people through economic and other human activity. As described in Chapter 2, ecosystem services are the contributions of ecosystems to benefits used in economic and other human activity.

3.2 This chapter discusses a number of measurement issues related to compiling information on ecosystem services in physical terms. The word "physical" in this context means "non-monetary" and measurement in "physical terms" encompasses ecosystem services that reflect flows of materials and flows of energy, services related to the regulation of an ecosystem, and flows related to cultural services. In Section 3.2 the focus is on further articulating the measurement boundaries for ecosystem services. A classification of ecosystem services is introduced in Section 3.3 and the basic approach to compiling accounts for ecosystem services is outlined in Section 3.4. Section 3.5 introduces 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 A fundamental aspect of ecosystem accounting is recognition that a single ecosystem 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 produced "in tandem", such as when forest areas are preserved and provide air filtration services as well as opportunities for recreation and walking. In other cases the ecosystem services may be in competition, such as when forest areas are logged thus providing the benefits of timber but losing opportunities for recreation. Ecosystem accounting enables the examination of these trade-offs.

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

i. *Provisioning services* reflect material and energy contributions generated by or in an ecosystem, for example a fish or a plant with pharmaceutical properties.

ii. *Regulating services*[29] result from the capacity of ecosystems to regulate climate, hydrological and bio-chemical cycles, earth surface processes, and a variety of biological processes. These services often have an important spatial aspect. For instance, the flood

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

[29] Regulating services are also commonly referred to as "regulation and maintenance services".

control service of an upper watershed forest is only relevant in the flood zone downstream of the forest.

iii. *Cultural services* are generated from the physical settings, locations or situations which give rise to intellectual and symbolic benefits that people obtain from ecosystems through recreation, knowledge development, relaxation, and spiritual reflection. This may involve actual visits to an area, indirectly enjoying the ecosystem (e.g. through nature movies), or gaining satisfaction from the knowledge 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 higher levels of an interim version of CICES.

3.6 Commonly, ecosystem services are conceptualised in terms of the types of benefits to which they contribute. In addition to distinguishing benefits as being either SNA or non-SNA benefits (as described in Chapter 2), a complementary view is to consider the private and public nature of the benefits. In terms of the generation of ecosystem services that contribute to private and public benefits three situations can be described.

(i) First, there are 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.

(ii) Second, there are ecosystem services that are generated from economic assets that are privately owned and managed but which contribute to the production of public benefits, i.e. the benefit accrues to other economic units or society more broadly rather than exclusively to the private owner/manager of the land (e.g. absorption of carbon dioxide by a privately owned forest).

(iii) Third, there are ecosystem services that are generated from areas that are not privately owned or managed and 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 comprise non-SNA benefits as described above. From an ecosystem accounting perspective, accounting for the second case is perhaps the most problematic since in this case 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 is 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 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 in relation to the private values of assets that are already included in the standard national accounts.

3.2.2 Relationship between 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 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 cities and large urban areas while the services are generated in ecosystems away from these areas. Although simple assumptions regarding the location of the beneficiaries cannot be made, it is important in accounting for ecosystem services that attempts are made to understand the likely areas in which beneficiaries are found. This information is needed to ensure that changes in the population of beneficiaries are taken into account in measuring the volume of ecosystem services. 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.

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

3.10 The majority of provisioning services are likely to be generated and used in the same ecosystem since it is necessary 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 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 to analyse the relationship between ecosystem services and a more complete series of transactions, including international trade flows, may be developed.

3.11 Overall however, while there is recognition of the need to relate the generation of ecosystem services with the location of the beneficiaries and the accounting logic is clear, there are measurement challenges involved that indicate a need for ongoing testing and the development of methods.

3.2.3 Measurement boundaries for ecosystem services

Supporting services

3.12 Chapter 2 noted that the definition of ecosystem services excludes the set of flows commonly referred to as supporting services. These include intra- and inter- ecosystem flows and the role of 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 and ecosystems. This notion of ecosystem services is often referred to as "final ecosystem services" in that they are the final outputs that are generated and used from an ecosystem. The focus on final ecosystem services

[30] This observation is also true for water since even though 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. river, lake) that is within a single ecosystem.

helps to avoid double counting the contribution of ecosystem services to the generation of benefits.

3.13 In concept, as described at a high-level in Chapter 2, it is possible to describe a series or chain of flows linking various intra- and inter-ecosystem flows with ecosystem services and subsequently to benefits. For certain analyses, “mapping” this chain may be particularly important in order to assess the ecosystem wide implications of specific decisions, for example to understand the impact of increasing harvest of timber from a forest. In practice, the complexity of ecosystem processes means that a detailed and complete accounting for supporting services is very difficult to support. As a consequence, the approach in SEEA Experimental Ecosystem Accounting is to account for ecosystem wide effects through assessments of changes in ecosystem assets. At the same time, mapping the chains of ecosystem flows may be important in certain situations.

3.14 While supporting services should be excluded, determining the final output of an ecosystem 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 both ecosystem services and supporting services and consequently overstate the contribution of ecosystem services in the generation of benefits. Put differently, the supporting services should be seen as an input to the ecosystem services which are therefore embodied in the flow of ecosystem services to benefits. Adding together supporting services and ecosystem services therefore represents a double counting of the contribution of supporting services.

Biodiversity and ecosystem services

3.15 As summarised in Chapter 2, the relationship between ecosystem services and biodiversity is complex. On the one hand, biodiversity is a core characteristic of ecosystems, and on the other changes in ecosystem extent and condition reflect changes in biodiversity.

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

3.17 However, biodiversity may be considered an important final ecosystem service in some circumstances and these 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.

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

Abiotic services

3.19 As noted in Chapter 2, 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, energy from the sun for the growing of crops and as a renewable source of energy, and the movement of wind and tides which can be captured to provide 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 conceptualised 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 3 and 5 of the SEEA Central Framework.

3.20 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 bio-physical, physico-chemical, and other physical processes and interactions within and between ecosystems – i.e. 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 provision from the environment is considered to be generated through ecosystem processes and hence the provision of water is considered an ecosystem service.

3.21 The importance of recognising abiotic services in ecosystem accounting lies in the organisation of information for the assessment of alternative uses of land. Most commonly there are trade-offs between baskets of ecosystem and abiotic services that can be made for alternative land uses. Examples of where these trade-offs may arise include cases where there may be use of agricultural land to establish mining operations, or cases where roads are extended into native vegetation. Considering these trade-offs only in relation to ecosystem services would reflect too narrow an analysis. The consideration of both ecosystem services and abiotic services provides a more complete assessment framework and confirms the need to use the accounting in both 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

3.22 In recognising a chain of flows between human well-being and ecosystems, the critical point in the chain for accounting is 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 relation to crops and other plants where there is a complex joint production process involving ecosystem services and human inputs, determining the distinction between inputs of ecosystem services and the generation of benefits may not be straightforward.

3.23 The involvement by economic units in the production of crops and other plants takes place along a continuum and there are varying degrees to which the growth of these biological

[31] It is also recognised that a number of resources considered abiotic, such as fossil fuels, are themselves the outcomes from ecosystem processes but on a quite different time scale.

resources is managed. Consequently defining standard rules by which the contribution of ecosystems can be measured is difficult. To date two main approaches have emerged to define a boundary for accounting purposes. The first approach measures the ecosystem services as equivalent to the amount of the crop that is harvested, irrespective of the extent of management of the growth of the crop. It may be referred to as the harvest approach.

3.24 The second approach distinguishes between the extent of management of growth by defining some crops as natural and some as cultivated following the logic outlined for the SNA production boundary. Where the crop growth is not managed (e.g. timber logged in naturally regenerated forests) the ecosystem service is equal to the amount of crop that is harvested. Where the crop growth is cultivated, the ecosystem services are equated to the combination of soil nutrient cycling, abstraction of soil water, pollination and other ecosystem processes involved in the growth of a plant that a grower utilises in combination with other inputs (labour, produced assets, fertilisers, etc). In either situation the measured ecosystem service still represents the input "purchased" from the ecosystem by the grower and hence the ecosystem service remains the final output of the ecosystem.

3.25 For ecosystem accounting there are a range of factors to consider

(i) First, it is likely to be useful in all measurement contexts to describe the chain of flows (including intra- and inter-ecosystem flows) related to cultivated and natural biological resources such that there is a full appreciation of the ecosystem linkages and to recognise that there are many points in the growth process at which human influence may occur.

(ii) Second, as part of describing the chain of flows it is likely to be relevant to organise the information according to the type of management or harvest technique being applied. For example, there are likely to be quite different effects on ecosystem assets from the use of small fishing boats compared to large trawlers even though the benefit extracted (fish) may be the same in both cases. Accounting for changes in management and harvest technique may be an important focus for ecosystem accounting.[32]

(iii) Third, 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.

3.26 Recognising the need for a measurement boundary to be drawn for accounting purposes, the proposed approach for SEEA Experimental Ecosystem Accounting is the second approach. This approach applies the SNA distinction between natural and cultivated growth processes for ecosystem services from biological resources noting that ideally the accounts would distinguish a number of management practices to better reflect different degrees of management intensity which, in turn, are likely to affect ecosystem assets in different ways.[33]

[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 recognised that this approach does not relate to an assessment of whether the associated ecosystem may be considered natural but rather it focuses on the degree to which the growth of the crop

3.27 This approach provides a measurement boundary for ecosystem services that aligns with the SNA production boundary and also the boundary for the Classification of Natural Inputs as described in the SEEA Central Framework. Importantly, the principles of the approach can be applied consistently across different types of cultivated biological resource (e.g. for crops, orchards, livestock, etc).

3.28 It is recognised 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 for livestock the ecosystem services is the same as proposed above being equal to the grass eaten. In concept, the approach used in MA, TEEB and other studies, uses principles relating to the removal of biotic resources from an ecosystem rather than consideration of the SNA production boundary.

3.29 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. This assumes that the various flows such as pollination, nutrients from the soil, and water that input to the growth of the mature crop flow 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) then this assumption may be reasonable.

3.2.4 Model for the measurement of ecosystem services

3.30 Building on the figures in Chapter 2 showing links between ecosystem assets, ecosystem services, benefits and human wellbeing, the following figure shows a model that may be used to place in specific context the measurement of ecosystem services and related flows. The example provided in Figure 3.1 relates to the provision of fodder for livestock. The figure shows flows related to ecosystem services, benefits, human inputs, and residual flows in relation to the relevant ecosystem asset (rangeland) and the associated economic activity of grazing.

3.31 Annex A3.1 shows further examples of the application of this model to selected provisioning, regulating and cultural services. The annex also discusses possible measurement approaches for the various ecosystem services.

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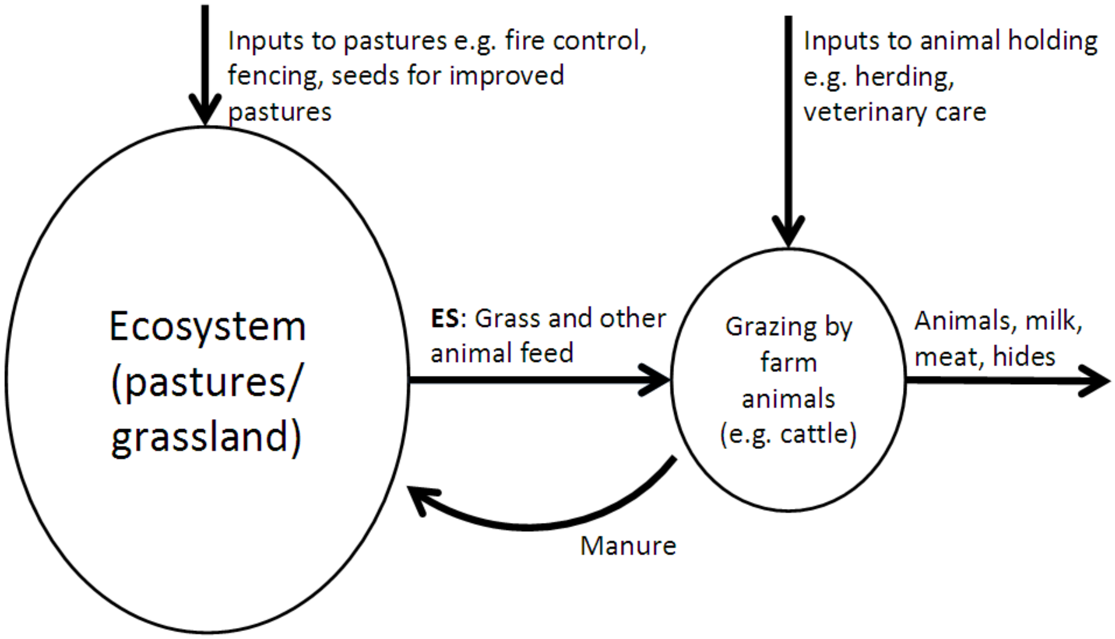
produced is more or less cultivated. Thus wild rabbits captured in agricultural lands would be considered to be grown naturally, i.e. uncultivated.

Figure 3.1. Provisioning of fodder for livestock



3.2.5 Other measurement issues

Defining volumes of ecosystem services

3.32 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 result reflects the starting point for accounting for ecosystem services being the use of ecosystems in economic and other human activity.

3.33 As a result of this logic, in concept, there may be no ecosystem services from a given ecosystem asset during an accounting period. However, it remains relevant to assess such an ecosystem asset for three reasons. First, there may be the capacity for an ecosystem asset to provide ecosystem services in the future and hence measures of the asset and changes in the asset are relevant. Second, the ongoing generation of ecosystem services may be highly variable or infrequent and 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 the ecosystem processes that generate ecosystem services in other ecosystems.

"Storage" of ecosystem services

3.34 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. This may be seen when certain natural resources available for use are not harvested during an accounting period and may increase through natural regeneration or replenishment. In accounting terms, these "unused" ecosystem services are recorded as increases in 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 only be recorded as ecosystem services in the period in which they are actually harvested. In effect, part of an ecosystem asset represents an inventory of natural resources that may be increased or decreased through regeneration or extraction.

Disservices

3.35 From a societal perspective there may often be outcomes from ecosystem processes that are seen as negatives (e.g. 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 ecosystem assets and a reduced supply of ecosystem services. However, other disservices that directly enter the production or consumption functions of households, enterprises and governments (e.g. natural pathogens having an impact on health) are not accounted for in the definition of ecosystem services outlined above.

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

3.37 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 some may be generated over quite large areas. Hence the notion of services being generated "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 to paid to the formation of meaningful spatial units (as discussed in Chapter 2) as this will provide a means to manage issues of scale and coverage in a systematic way.

Flows of ecosystem services between countries

3.38 There are a number of aspects to consider concerning flows of ecosystem services between countries. First, there are some regulating services, for example carbon sequestration, where

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

the provision of the service provides benefits to all people irrespective of the location of the relevant ecosystem. From an accounting perspective it would be possible to record imports and exports of ecosystem services in this situation reflecting the distinction between the generation of the service and the location of the beneficiaries. Similar, but smaller scale, transactions might be recorded in relation to air filtration and water purification services between neighbouring countries.

3.39 Second, non-residents visiting a country are likely to use ecosystem services and, similarly, residents visiting another country are likely to use ecosystem services from 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 an import of an ecosystem service in the accounts of the country undertaking the fishing.

3.40 Finally, it is noted that there are likely to be inter-ecosystem flows that cross country boundaries. Flows of water via major rivers are a particular example. As described, inter-ecosystem flows are not flows of ecosystem services however these flows should be recorded as 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

3.41 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 picture of ecosystem accounting by providing a structure to classify those flows defined as ecosystem services. It does not provide a structure to classify ecosystem assets, ecosystem processes, ecosystem characteristics, abiotic services or benefits. Figure 2.3 in Chapter 2 places all of these parts of ecosystem accounting in context.

3.42 At the broadest level three different categories of ecosystem services are distinguished in SEEA Experimental Ecosystem Accounting: (i) provisioning services; (ii) regulating services; and (iii) cultural services, as defined in Section 3.2.

3.43 Table 3.1 presents the higher levels of CICES and experience to date suggests that at this broad level the structure of CICES can be used in a range of situations. The table also provide 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.

3.44 There are three important boundaries in relation to CICES.

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

(ii) 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 recognised that many of the regulating services may also be considered supporting services depending on their place in the chain of ecosystem flows. However, CICES is a classification of those flows that have been defined as “final” ecosystem services and hence should be used only to classify these flows.

(iii) Third, consistent with the proposals 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/natural crops and other plants, the ecosystem services are measured by the harvested products.)

3.45 If a choice is made to use an alternative boundary for the measurement of ecosystem services related to crops and other plants, then some adaptation of the CICES would be required. It is noted that 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, abstraction of soil water, etc. Put differently, both pollination and harvested crops should not be combined in a measure of “final” ecosystem services. This would represent a “double count” in accounting terms.

3.46 The 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

3.47 The aim of accounting for ecosystem services is to organise 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.

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

3.49 Where an LCEU is completely contained within an EAU no attribution of observed physical flows to finer spatial levels, i.e. to 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 BSU. is likely to be required in order to permit attribution to the EAU level.

[35] Materials relating to the development of CICES and other documents relating to the classification of ecosystem services are listed in the References annex.

Table 3.1 Three levels of CICES

CICES for the SEEA Experimental Ecosystem Accounts				
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.
		Uncultivated terrestrial plants and animals for food	Uncultivated terrestrial plants and animals (e.g. game animal, 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 the uptake by crops; fodder for livestock; feed for aquaculture product;	Crops and vegetable products; cultivated timber and cotton; cattle for meat and diary product; aquaculture product;
		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. fertiliser 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 medicine use, manufacturing or domestic production	Substances and biochemicals, such as rubber, enzymes, gums, oils, wax, herbs to cosmetic and medicinal use or for further processing in the manufacturing industry
	Materials	***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 animal trained to harness	Work and pet animals

CICES for the SEEA Experimental Ecosystem Accounts--Continued

Section (1-digit)	*Division(2-digit)*	*Group (3-digit)*	**Examples of ecosystem services**	**Examples of benefits**
Regulating	***Remediation and regulation of biophysical environment***	***Bioremediation***	Chemical detoxification/breakdown of pollutants by plants, algae, micro -organisms and animal.	Reduced level of pollutant/contaminants in soil and ground water
		Dilution, filtration and sequestration of pollutants	Dilution of municipal wastewater in rivers, removal of organic materials and nutrients from wastewater by biogeochemical process; filtration of particulates and aerosols; sequestration of nutrients and pollutants in organic sediments, removal of odours.	Cleaner air, water and soil
	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 the urban area.
		Water flow regulation	Regulation of timing and magnitude of water runoff, flooding and aquifer recharge	Prevention of flood damage; recharge of water into surface water and ground water; reduced damage from high water.
		Mass flow regulation	Soil and mudflows stabilization	Prevention of soil erosion, avalanche 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 gas in the atmosphere; Reduced impact of climate change; Improvement of the climate condition.
		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	***Lifecycle maintenance, habitat and gene pool protection***	Pollination, seed dispersal, maintenance of habit nursery population and habitats	Improvement of productivity of crops, habitats conservation
		Pest and disease control (incl. 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 species for hiking, bird recreation	Enjoyment for hiking, bird watching, whale watching, etc.; Increase health level; increased number of visitor in the tourism industry
		Information and knowledge	Landscape character and biodiversity species for scientific research and education	Scientific progress (e.g. such as pollen record, tree ring record, genetic patterns); Increase knowledge (e.g. subject matter for wildlife programmes and books) etc.
	Intellectual representations of ecosystems [of environmental settings]	***Spiritual & symbolic***	Landscape character and biodiversity species for cultural heritage values, sense of personal and group identity (sense of place), spiritual and religious function, etc.	Increase sense of personal and group identity, national symbol, performance of spiritual and religious functions.
		Non-use	Ecosystem capital for future generation of ecosystem services.	Availability of biodiversity and ecosystem services to future generation.

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

3.4.2 Measurement units for ecosystem services

3.51 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. 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, usually one year.

3.52 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 terms of tonnes of carbon sequestered.

3.53 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.

3.54 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 focus may be placed on increases or decreases in flows of ecosystem services over time. Implicitly however, such a presentation may suggest that each ecosystem has an equal weight and thus the relative significance of each service would not be clear.

3.4.3 Possible tables for ecosystem services

3.55 Table 3.2 below presents a basic table that may be used to record estimates of the physical flows of different ecosystem services. It may be best to envisage this table being constructed for a country as a whole (the highest level of EAU) which is composed of numerous LCEU 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. This is likely to be appropriate for many provisioning and cultural services but may not be appropriate for some regulating services (e.g. water flow regulation).

3.56 No row is included to reflect a total flow of different ecosystem services. This is because the aggregation of estimates across different services is not straightforward and is subject to considerable caveats. The following sub-section discusses relevant approaches and concerns.

Table 3.2 Physical flows of ecosystem services for an EAU

	Type of LCEU				
	Forest tree cover	Agricultural land*	Urban and associated developed areas	Open Wetlands	…
Type of ecosystem services (by CICES)					
Provisioning services	e.g. tonnes of timber	e.g. tonnes of wheat			
Regulating services	e.g. tonnes of CO_2 stored/released	e.g. tonnes of CO_2 stored/released	e.g. tonnes of CO_2 stored/released	e.g. tonnes of P absorbed	
Cultural services	e.g. number of visitors/hikers		e.g. hectares of parkland	e.g. hectares of duck habitat	

* Medium to large fields rainfed herbaceous cropland

3.57 By definition the total generation of a single ecosystem service should equal to the total use of that service. However, the use 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 recognising those services that are used by people within the EAU and those used by people outside the EAU.

3.58 The attribution of the generation of ecosystem services to type of economic unit (enterprises or 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 3.3 shows a possible way of organising 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 3.3 Generation and use of ecosystem services for an EAU

	Generation of ecosystem services					**Use of ecosystem services**				
	Enter-prises	Households	Govern ment	Rest of the world	Total	Enter-prises	Households	Govern ment	Rest of the world	Total
Type of ecosystem services (by CICES)										
Provisioning services										
Regulating services										
Cultural services										

3.59 A full articulation of ecosystem service flows requires consideration of flows to and from the rest of the world. These flows are of two main types. First, there are ecosystem service flows between countries that reflect the generation of ecosystem services in one country where 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.

3.60 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 by consumed by non-resident beneficiaries may be considered exports.

3.61 In Table 3.3 the columns labelled “Rest of the world” include both of these types of flows between countries and their resident economic units. Ideally, these different types of flows should be distinguished. It may also be useful for analytical purposes to determine what proportion of use of ecosystem services by domestic economic units (enterprises, government, households) is supplied by ecosystem services from 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 service 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 framework.

3.62 Depending on the purpose of analysis it may be relevant to also include measures of abiotic services for particular spatial areas (EAU or 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.

3.63 Information organised following the broad structure in Table 3.3 may be compared directly with information on economic activity organised following the standard economic accounts. For example, information on the use of ecosystem services by enterprises may be compared directly to measures of intermediate consumption and output of enterprises, possibly classified by industry. Estimates of use of ecosystem services by households can be directly compared to 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 as extensions to the standard production account of the SNA. The implications are described in more detail in Chapter 6.

3.4.4 Approaches to aggregation of ecosystem services

3.64 In the context of ecosystem accounting, aggregation involves bringing together information about a particular spatial area to provide overall measures of flows of ecosystem services. Three different forms of aggregation can be envisaged. First, there is aggregation of the various ecosystem services within a spatial area (for example within an EAU). Second, there is aggregation of a single ecosystem service across multiple spatial areas within a country (for example, across multiple LCEU). Third, there is aggregation of all ecosystem services across multiple (potentially all) areas within a country.

3.65 Before considering methodological issues in aggregation, compilers should consider carefully 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.

3.66 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. Given this, aggregation requires some assumptions regarding the relative importance or significance of each of the ecosystem services. This is done by establishing weights that reflect the relative importance of each service.

3.67 There are a number of possibilities to determine weights for ecosystem services. One alternative is to assume that each service has equal weight. Another alternative is to calculate a price in monetary units for each service (see Chapter 5 for discussion of this issue). A third alternative is to derive weights based on a common "currency", for example in terms of hectares or units of carbon, where different physical measures are converted into a common measurement unit.

3.68 Two methods of aggregation to derive overall measures using a set of weights may be followed depending on the type of weights being used. The first method involves the construction of a composite index. This requires converting all physical flow measures into 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 form an average index number value for that period. In the first or base period the average will equal 100. In effect different rates of change in the various service flows are given different levels of significance.[36]

3.69 The second method involves the summation of observations that have been converted into a common unit of measure. An example of this is the use of prices to convert physical measures to monetary values. The monetary values of each service can then be summed to provide an aggregate measure.

3.70 Clearly, the derivation of aggregates involving a number of different ecosystem services depends heavily on the choice of weights. Without a robust rationale for the chosen 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 variation in aggregate values in response to variations in the weighting patterns). However, this should not be seen as a substitute for understanding the conceptual implications of choosing a particular type of weights. This is especially the case when considering the use of prices given the conceptual and practical complexities described in Chapter 5.

3.71 Beyond the choice of weights the other significant issue in aggregation across different ecosystem services is the extent to which the measured ecosystem services provide a complete coverage of all ecosystem services. Indeed, inadequate coverage may be a more significant issue in terms of the interpretation of aggregates than the selection of weights.

3.72 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

[36] Additional details on the compilation of composite indicators are provided in an OECD/JRC handbook.

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. However, often in ecosystem services measurement it is necessary to estimate flows of ecosystem services using data from various sites and then to use scaling and transfer techniques (discussed in Chapter 2) to provide estimates for other areas. In these cases it is assumed that differences in quality of ecosystem services between areas are taken into account by adjusting for any variations in ecosystem characteristics.

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

3.5 Measuring ecosystem services

3.74 This 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 not possible to identify and define all ecosystem services. An annex describes potential approaches to the measurement of a range of ecosystem services (see Table 3.4 below) in physical terms in order to assist compilers in commencing work on the measurement of ecosystem services and to better explain the measurement concepts.

Provisioning services

3.75 Provisioning services 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 may mean that a range of additional information is required in order to measure flows related to these cultivated resources.

Table 3.4 List of selected ecosystem services described in annex

Name of ecosystem service	Description of ecosystem service	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 that may be harvested. Non-timber forest products include for instance rattan, various food products, genetic materials, ornamentals, and pharmaceutics.	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 that 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 use in other economic activity (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 to floods	Protection of properties and lives
Cultural services		
Providing opportunities for tourism and recreation	Ecosystems provide physical space and landscape features people enjoy view, or undertake activities in (hiking, cycling)	Recreational benefits

Regulating services

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

3.77 These other conditions and factors differ for the various regulating services. Note that these conditions and factors are typically not a characteristic of an ecosystem, and they are not reflected in measures of ecosystem assets. Nevertheless, they need to be understood, quantified and recorded before physical and monetary measurement of the ecosystem service can take place.

3.78 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

3.79 Cultural services are generally more difficult to define than provisioning and regulating services since they reflect the nature of human 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 are direct contributions to economic activity, particularly the opportunities provided by ecosystems for the production of tourism and recreation services. Also, some cultural services will be implicit in the values placed on land ownership, for example the amenity value of a scenic view. Thus, there may be a range of cultural services for which the evidence is present in the undertaking of various activities and the outlay of expenditures.

3.80 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 surrounding landscape.

Setting priorities for measurement of ecosystem services

3.81 In piloting ecosystem accounting at the national scale, it may be most feasible to initially select a limited rather than a comprehensive set of ecosystem services for inclusion in ecosystem accounting exercises. The potential feasibility to measure ecosystem services at the national scale, both in physical and in monetary terms, differs strongly between different ecosystem services. These differences occur due to differences in data availability, different methodological constructions, and different complexities related to scaling up and aggregating physical and monetary units associated with ecosystem services. In addition, there may be different policy priorities for analysing ecosystem services.

3.82 To facilitate the selection process of ecosystem services in ecosystem accounts, a list of criteria for ranking ecosystem services with regards to their potential suitability for inclusion in ecosystem accounting is presented in Table 3.5 below. The applicability of the criteria will differ between countries and the list should be seen as indicative only.

3.83 Environmental concerns, data availability and policy contexts will differ in each country, hence the selection of ecosystem services for ecosystem accounting will differ. In general, from a methodological and data perspective, often most feasible for ecosystem accounting are the provisioning services including water supply, since the benefits arising from these ecosystem services are generally measured as part of standard economic accounts. While measurement of provisioning services may be useful to understand the relative dependence of economic activity on ecosystems, the additional value of ecosystem accounting lies in 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.

Table 3.5 Criteria for 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 / well reflect changes in natural capital stocks.
2	Likelihood of irreversible loss of ecosystem services including by the supplying ecosystem being pushed past a significant threshold and out of its "safe operating range".	Consideration may be given to services that are generated from ecosystems that are generally understood to be close to significant environmental thresholds.
Policy context		
3	Possibility to influence environmental and/or economic policy and decision making (decision making context)	Consideration may be given to services that can relatively easily be influenced by decision making in order to have maximum relevance for policy making.
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 analyzing ecosystem services supply in physical terms at a high aggregation level	Consideration may be given to services for which broadly accepted modelling / quantification techniques are available.
6	Availability of broadly accepted methods for analyzing ecosystem services supply at a high aggregation level 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 a national level based on underlying spatial data. Both point-based data and spatially explicit data (e.g. land cover, soils, water tables, ecosystem productivity, etc.) 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 intent or high likelihood that new environmental monitoring will provide essential data.

3.84 As part of broadening the coverage of ecosystem services, the measurement of water and carbon are two areas that may be considered for particular focus. 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, with regards to such aspects as water purification in aquatic ecosystems or in the soil, water storage in ecosystems in upper watersheds, etc. 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 aggregation levels, 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 SEEA Water and a companion standard, the International Recommendations for Water Statistics.

3.85 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 research on-going aimed at quantifying these services at different scales, from local processes to national stocks and flows. The development of REDD (Reduced Emissions from Deforestation and Degradation) market mechanisms means that there is also, increasingly, information available on markets related to carbon. Given the broad interest and the increasing availability of methods and data relevant for this service, this service has a high potential for inclusion in ecosystem accounts.

3.86 A challenge with regard to these ecosystem services is to account for both the storage and the sequestering of carbon. Storage and sequestering are not aligned. 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), but this does not need to be the case (e.g. in a desert).

3.87 It should be noted however, that although scientific methods and data are relatively well developed for this service, this does not equally apply to all ecosystems, with relatively much data available for forests, and relatively few data 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/landscape mosaics. Further discussion relating to accounting for stocks and flows of carbon is presented in Chapter 4.

Annex A3.1: Models for the measurement of selected ecosystem services

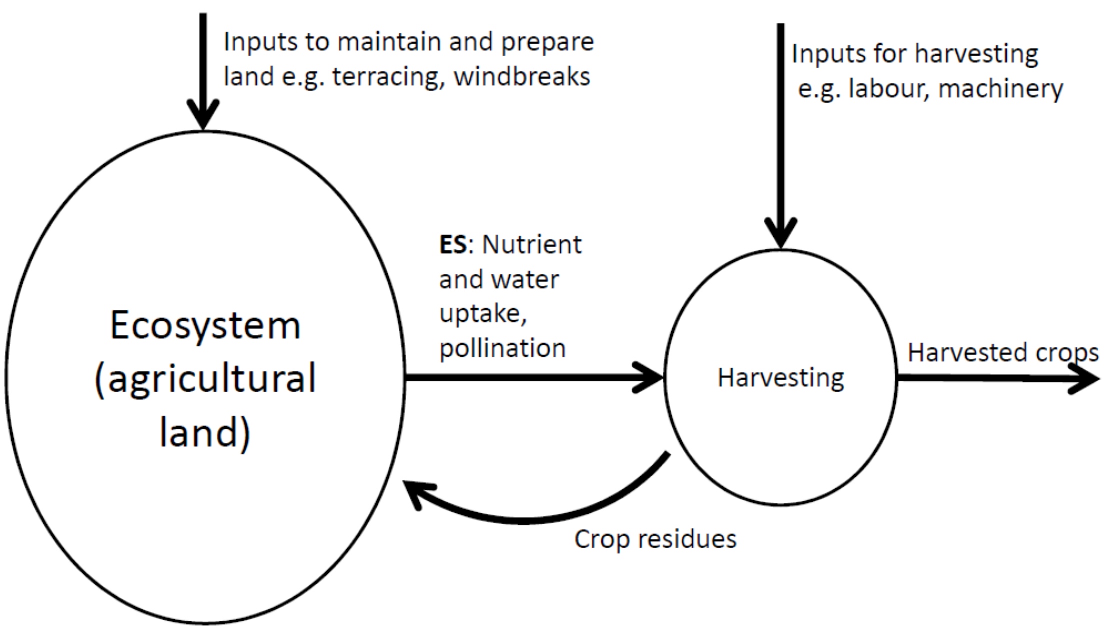
A3.1 This annex provides examples of measurement approaches for some selected ecosystem services. It is recognised that presenting the information in this de-constructed way may give the impression that ecosystem services are easily separable flows. In reality, the measurement of ecosystem services must start from a more holistic sense of an overall ecosystem and the range of different services that effectively emerge from the ecosystem as a bundle of services. However, as a matter of statistical and scientific approach, direct measurement of this bundle is not possible and hence a decomposition must be adopted.

Provisioning services

Provisioning services for crop production

A3.2 Crop production includes the production of annual and perennial crops in cultivated land including plantations, see Figure A3.1. The ecosystem services associated with crop production comprise pollination, abstraction of soil water and soil nutrient uptake and fixation. The farmer or land manager (i) manages, on a regular basis, the overall production environment, i.e. the farm or plantation, for instance by constructing wind breaks or irrigation reservoirs, pruning, etc; and (ii) harvests crops using labour and machinery. In practice, it may not always be easy to distinguish between 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**

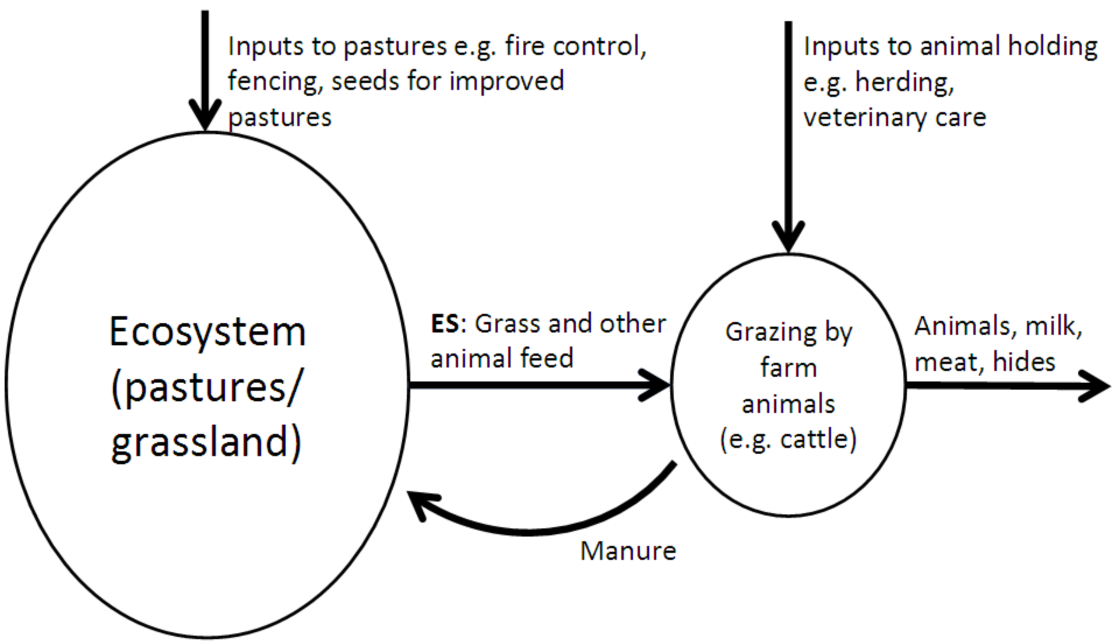


Provisioning of fodder for livestock

A3.3 In livestock grazing, the service supplied by the ecosystem relates to the amount of animal fodder grazed by livestock. This animal fodder comprises 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 large stretches of semi-arid rangeland, or dairy cattle grazing 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 in terms of amount of fodder grazed by animals on an annual basis. Fodder will normally comprise different types of quality (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**



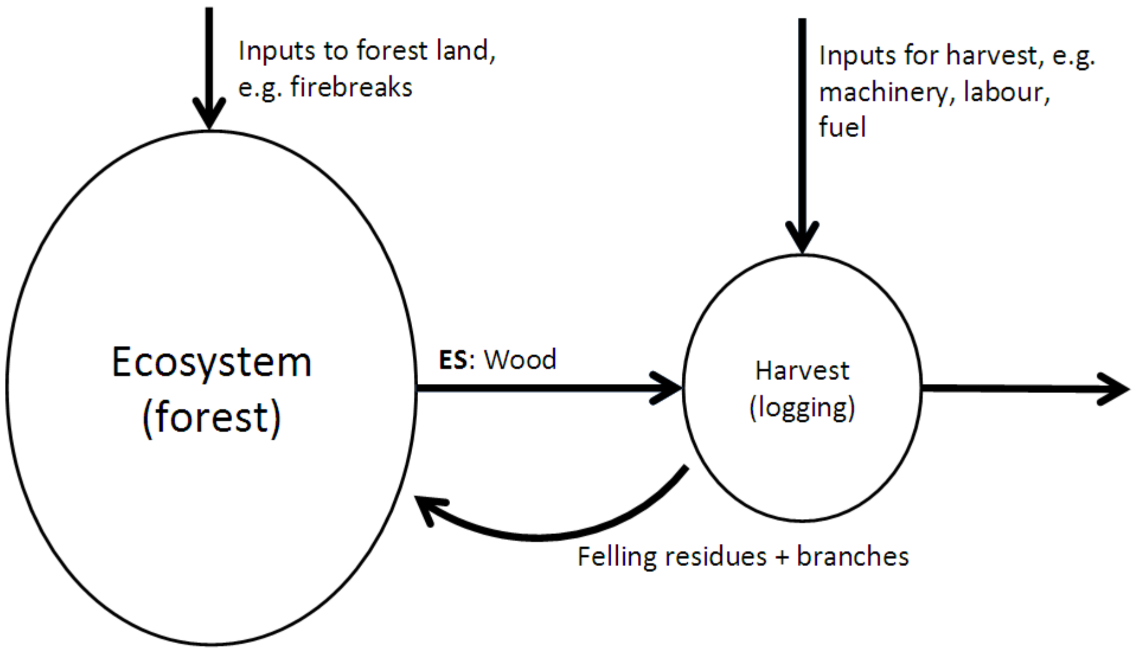
Provisioning of wood and non-timber forest products

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 evidenced by relatively significant levels of economic activity in the growing process including the construction of fire breaks, 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 NTFP are presented in Figure A3.3 while the flows related to wood from plantations should be shown following the same logic as presented in Figure A3.1 in relation to provisioning services for crops.

A3.7 For logging, a number of inputs are required such as labour, a saw and a truck. The product resulting from the logging is logged wood, with felling residues returned to the ecosystem. Wood can have a wide range of different qualities. Both the benefit (logged wood) and the ecosystem services (wood) can be measured in terms of kg/ecosystem/year. The difference between the two is that the ecosystem service represents wood at the moment immediately before it is felled. The benefit arises immediately after 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, rivers) supply fish and other species (shrimps, shellfish, seaweed, etc.). There is generally little investment in maintaining the state of the ecosystem, even though monitoring or enforcement activities may be undertaken, and on specific occasions also 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 fishing is also fish. The ecosystem service may be measured in physical terms in terms of the amount of fish caught (i.e. the gross removal from the ecosystem), accounting for differences in species. Discarded catch is usually returned to the ecosystem. Often the discarded catch consists mainly of dead specimens that 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 in the case of livestock. Thus the natural feed and other natural inputs are the ecosystem services representing 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 (for example fish raised 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 geological water resources. The extraction of water from deep aquifers storing water that is not replenished on human time scales should therefore be interpreted as flows of abiotic services.

A3.12 For both surface water and water extracted from renewable, 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 breakdown or bind pollutants and filter micro-organisms harmful to human health. Often, headwaters or complete watersheds important for drinking water production are protected and managed as drinking water extraction area.

A3.13 Water supply therefore combines elements of 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 the surface water source or the shallow aquifer.

A3.15 Investments may be made in order to protect the ecosystem (generally a watershed) supplying the water (e.g. adjusted land management, monitoring of water quality, creation of retention basins) as well as for the transformation of 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

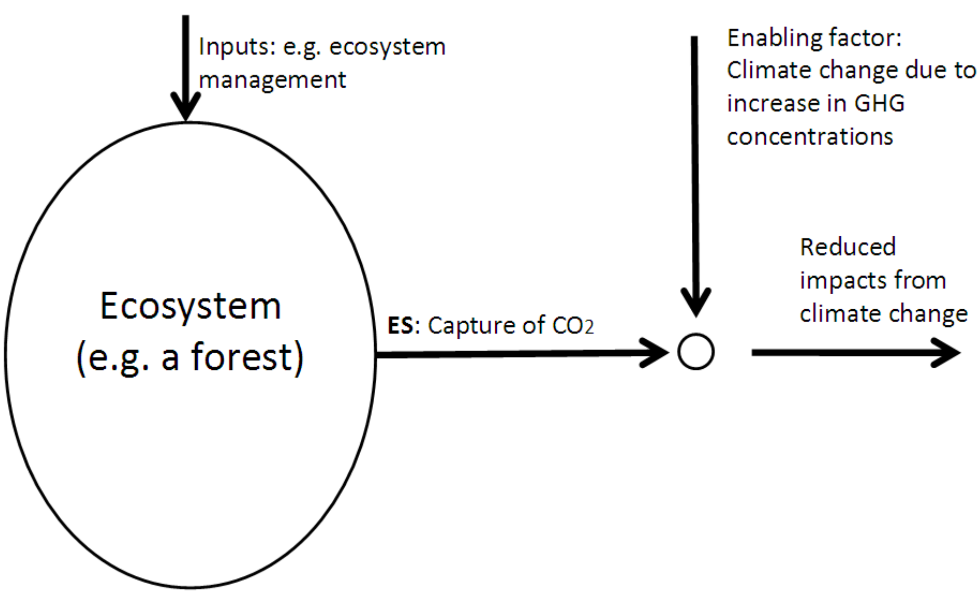
A3.16 Often, the services of sequestering of carbon and carbon storage are labelled by the single term "carbon sequestration". However, they are quite different ecosystem services, albeit linked within the broader carbon cycle. Both services are important for ecosystem management and therefore for ecosystem accounting. The release of carbon stored in above ground biomass or in below ground stocks, such as peatlands, is an important source of greenhouse gas emissions worldwide. It is also the subject of much debate in the international arena, in particular with regards to the REDD (Reduced Emissions from Deforestation and Degradation) payment mechanism. At the same time, the sequestering of carbon, i.e. the ongoing accumulation of carbon due to ecosystem processes in particular Net Ecosystem Production, is relevant since this removes carbon dioxide from the atmosphere.

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

A3.18 To calculate the second part, i.e. the flow that can be attributed to maintaining carbon in storage, the avoided emissions may be calculated. Under this approach the avoided emissions only relate to the part of the stored carbon that is at clear risk of being released in the short term due to land use changes, natural processes (e.g. fire) or other factors. No service flow is recorded if stocks at risk of being released are 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. Figure A3.4 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 an economic benefit resulting from avoided damages, at present and in the future.

Figure A3.4 Sequestering of carbon



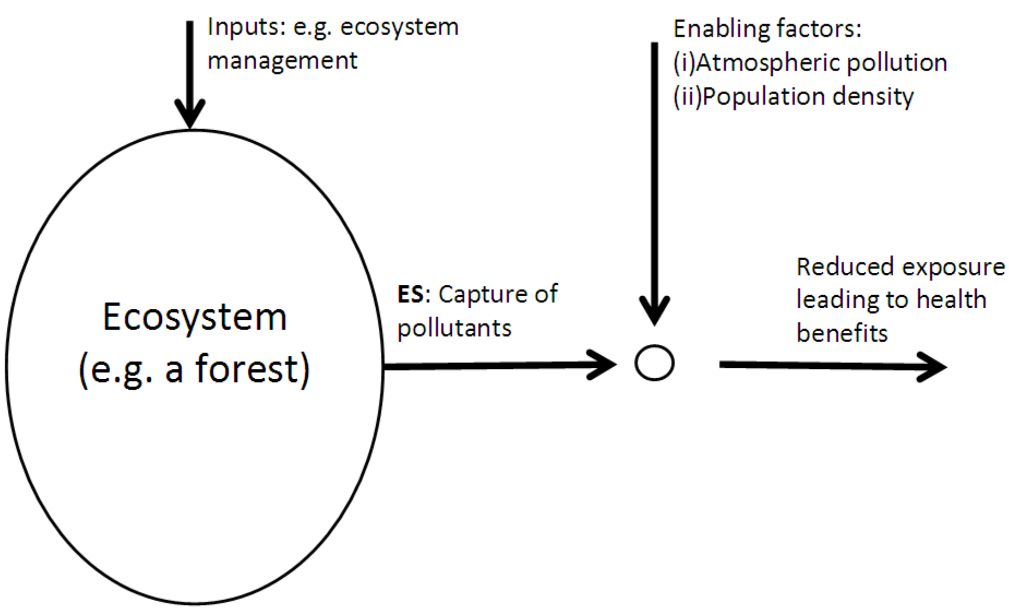
Air filtration

A3.20 Air pollution arising from particulate matter (in particular the smallest fraction of PM: PM2.5 with a diameter <2.5 μm) 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 shown 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. First, there needs to be a certain pollution load (that can be measured in terms of PM concentration), and second, there needs to be 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↓ = A*Vd*t*C, in which PM↓ = deposition of PM2.5 (kg), A= area (m^2), Vd = 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/m3). The deposition velocity depends on the vegetation type, and there is an increasing number of measurements of deposition velocities as a function of vegetation type, in particular in European countries.

A3.22 A cause of uncertainty pertains to the distance at which vegetation influences air quality. The UK National Ecosystem Assessment assumed that health benefits from air filtration by forests only occur 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 over distances of several hundreds of kilometres from an emission source, which means that the effect of large forests on air quality may be noticeable at large distances from the forest edge.

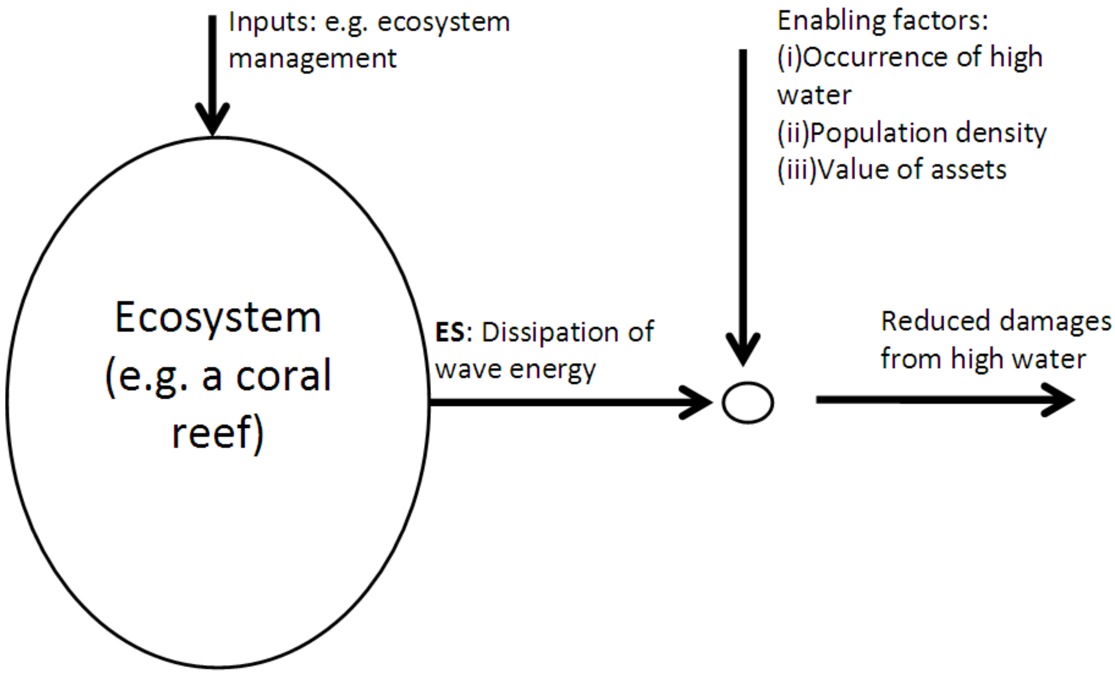
Figure A3.5 Air filtration



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, or riparian forests, are particularly relevant in this regard. This service is only relevant where there is (i) risk of high water and wave energy as a function of wind patterns and local bathymetrics; and (ii) 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 involves the dissipation of wave energy and the prevention of inundation. In inland areas, the ecosystem service involves the channelling and dispersion of water.

Figure A3.6 Flood protection



Cultural Services

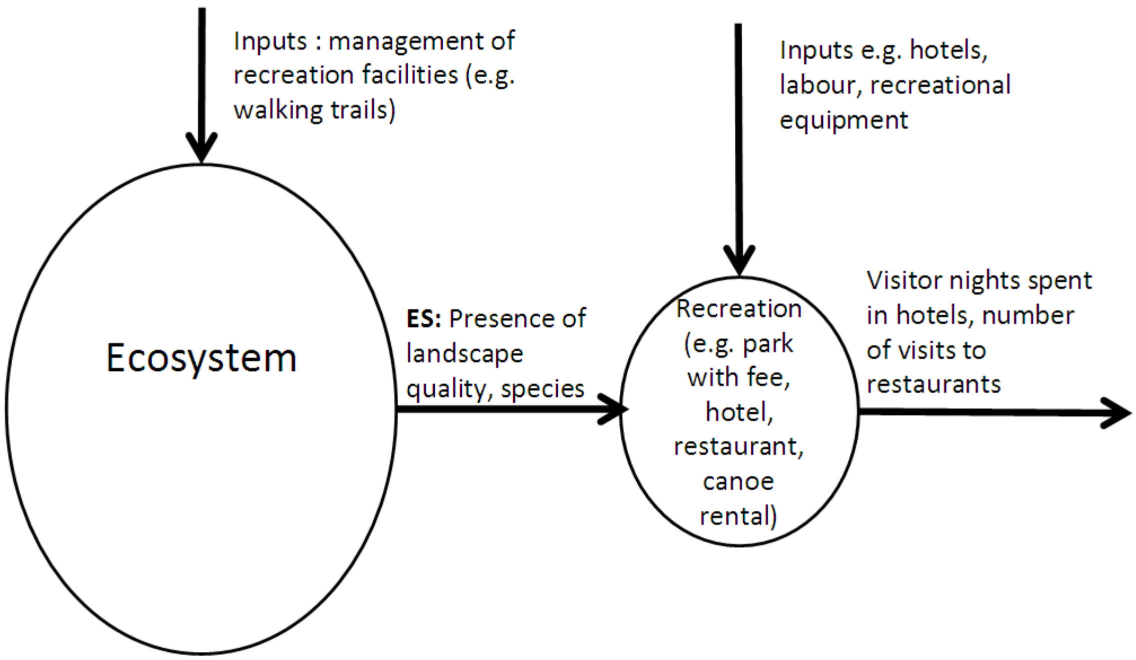
Tourism and recreation

A3.24 Ecosystems provide an opportunity for tourism and recreation. Tourism is generally interpreted as involving overnight stays, potentially 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 in terms of the number of people visiting the ecosystem.

A3.25 The benefits accrue to visitors themselves, and to nearby suppliers of tourism and recreational facilities to the extent that they can attribute their operation to the ecosystem. For instance, some tourism facilities only exist 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, in terms of visitor-days, or overnight stays, to ecosystems. Areas such as national parks that are publically accessible are most relevant for this service. As in the case of provisioning services, the use of ecosystem services in tourism involves a specific activity being undertaken, i.e. the recreation activities by people in an ecosystem.

Figure A3.7 Tourism and recreation services



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 from two perspectives. First, ecosystem assets are considered in terms of *ecosystem condition* and *ecosystem extent*. Second, ecosystem assets are considered in terms of *expected ecosystem service flows*. In general terms, 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 neat or simple relationship between these two perspectives. Rather the relationship is likely to be non-linear and variable over time. For example, if an ecosystem asset such as a river basin, has a capacity to provide a significant amount of water for human consumption then it may be that increases in population (up to a certain point) lead to no change in ecosystem condition while ecosystem services will rise. Also, there may be dependencies between ecosystem assets such that declines in ecosystem condition in say spawning grounds for salmon ultimately impact on 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 in terms of changes in ecosystem condition 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 the asset are insufficient and it is important that both the ecosystem service flows and the ecosystem condition and extent are 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 most relevant aspects of ecosystem assets from the perspective of providing aggregated information for measuring trends and comparing ecosystem assets for policy and analytical purposes.

4.5 With this in mind, the approach outlined here involves (i) a decomposition of ecosystems into relevant characteristics, and (ii) an assessment of each characteristic in the context of the ecosystem as a whole. From this set of information, conclusions may be drawn about the overall condition of the ecosystem and its capacity to deliver ecosystem services based on expected patterns of ecosystem use. In addition, using information on flows of ecosystem services as described in Chapter 3, expected ecosystem service flows based on expected patterns of ecosystem use can also be estimated. Assessments of ecosystem degradation and ecosystem enhancement can be made using information on 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 to determine the relevant indicators. In particular, it is important not to lose sight of the fact that ecosystems function by all components working together and it is not necessarily a simple case of adding together an assessment of each characteristic.

4.7 This 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 including discussion on the aggregation of various indicators. The final two sections summarise accounting for two specific aspects of ecosystem asset accounting – accounting for carbon (Section 4.4) and accounting for biodiversity (Section 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: ecosystem condition, ecosystem extent, and expected ecosystem service flows. These concepts were introduced in Chapter 2. This section provides additional discussion of the relevant concepts in combination with approaches to measurement. There are strong relationships between 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 land cover although the accounting 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 LCEU (e.g. forests, wetlands, etc). The measurement of ecosystem extent will identify the location of an ecosystem asset on the surface of the Earth and the location in relation to other ecosystem assets. 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, etc 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 scientific basis such 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 understanding the condition of an ecosystem asset. Inter-ecosystem spatial characteristics, such as connectivity and landscape configuration, are a type of ecosystem characteristic.

4.13 It is noted that individual ecosystem characteristics are not considered to be ecosystem assets in their own right. In some cases, for example, for water resources and soil resources, it is possible to undertake distinct asset accounting. This is 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 There are a number of conceptual alternatives available to determine a reference condition. One approach from the perspective of accounting is to measure changes relative to the condition at the beginning of the accounting period. Thus, when compiling accounts for any given accounting period, the measure of change in condition should 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 all are assumed to have the same condition relative to their specific characteristics at the beginning of the period.

4.16 Alternatively, a reference condition of particular importance for ecosystem accounting relates to the degree or nature of human influence within an ecosystem. This may also be expressed as a condition reflecting an ecosystem which is relatively undisturbed or undegraded by humans, or should reflect a situation in which the ecosystem is in relative stability. For example, long standing agricultural areas may be considered to be ecosystem assets that are relatively stable and not degrading in terms of their ecosystem characteristics (e.g. soil condition) and their capacity to provide a stable flow of agricultural products.

4.17 A particular feature of using reference conditions is that ecosystems that are naturally more structurally diverse or species rich (e.g. tropical rainforests) are not necessarily assessed as having higher condition compared to ecosystems that are naturally less structurally diverse or species rich (e.g. Arctic tundra).

4.18 One approach to applying a reference condition concept 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 multiple ecosystem assets, it is possible to make assessments of the relative condition of different ecosystem assets. Within this approach, one choice may be to select a point in time before significant patterns of recent landscape change due to human activity were in evidence. Selecting more recent periods as reference conditions would effectively treat equally ecosystem assets that may range from relatively natural to relatively human influenced.

4.19 While reference condition accounting leads to the recording of ecosystem condition scores between 0 and 100, these scores cannot be used to infer 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 In this context it is relevant to distinguish a reference condition from what may be regarded as a target condition. A target condition is one that 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 hence flows of particular ecosystem services. Ecosystem accounting does not involve the use of target conditions. The use of a reference condition therefore does not imply that all ecosystems should, ideally, have a condition score of 100. Rather a reference condition provides a comparison point that can be scientifically assessed over time.

4.21 Most focus in condition accounting is on changes in condition and extent over time rather than the actual condition score. However, while the actual ecosystem condition may not be a key indicator in some circumstances, there may be known thresholds in ecosystem condition such that, where the condition of particular characteristics falls below relevant thresholds, the whole ecosystem may be in danger of collapse. Thus at high degrees of human influence, the actual condition scores may 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 It is noted that 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 a part of measuring 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 second perspective on ecosystem assets focuses on assessment of the capacity of an ecosystem asset to generate an expected combination (or basket) of provisioning, regulating and cultural services from an ecosystem asset. Because the generation of some ecosystem services involves the extraction and harvest of resources, and since ecosystems can regenerate, it is necessary to form expectations on the amount of extraction and the amount of regeneration that will take place, and on the overall sustainability of human activity in the ecosystem.

4.25 Moreover, expected ecosystem service flows are dependent upon assumptions regarding future use patterns. In general there will be differences between current use patterns (e.g. where a fishery may be “over-fished”) or alternative use patterns (e.g. fishing at a sustainable yield).

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

4.27 There are generally relationships between the condition of an ecosystem asset, its pattern of use, and the expected basket of ecosystem services. Thus 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 for other services.

4.29 It is through the lens of ecosystem services that it is possible to make the connection between ecosystem condition and extent, the benefits obtained, and broader measures of economic and human activity. Thus measurement of expected ecosystem service flows is important in the consideration of trade-offs between ecosystem services and, more broadly, between alternative land uses. Because of the general framework in which ecosystem services sit (see Figure 2.3) this expected flow perspective on the measurement of ecosystem assets can be combined with a broader assessment of both 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 ecosystem assets may change for a variety of reasons both natural and human induced and the different perspectives on the measurement of ecosystem assets open up a number of considerations.

Ecosystem degradation and ecosystem conversions

4.31 In general terms, 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 involve the following two conditions:

(i) That ecosystem degradation covers only declines due to economic and other human activity - thereby excluding declines due to natural influences and events (e.g. forest fires or hurricanes)[37]

(ii) That declines in expected ecosystem service flow where there is no associated reduction in ecosystem condition should not be considered ecosystem degradation

[37] Declines due to natural events are recorded in ecosystem asset accounts but are not considered a part of ecosystem degradation.

(e.g. where, *ceteris paribus*, provisioning services from forests decline because of reduced logging due to decreases in expected output prices, or declines in cultural services due to a rise in national park entry fees).

4.32 This approach to conceptualising ecosystem degradation is particularly relevant in situations where the extent of an ecosystem asset does not change over an accounting period, or more specifically in the case of ecosystem assets defined by EAU (whose area will generally remain stable), when the composition of an EAU in terms of areas of different LCEU does not change. However, where the extent or composition of an ecosystem asset changes significantly or irreversibly (e.g. due to deforestation to create agricultural land) the consequences for the definition of ecosystem degradation are less clear and will relate to the scale and complexity of 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 a decrease or an increase in expected ecosystem services flows from that area. If it is the former then an argument may be made to call this decrease ecosystem degradation. However, since the general effect of ecosystem conversions is for there to be 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. It 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/to the converted ecosystem asset. Adjacent ecosystem assets may thus also become degraded.

4.34 Another perspective in cases of ecosystem conversions is to focus only on changes in ecosystem condition in the area within the ecosystem asset that has been converted, e.g. the part of the forest that has been converted to agricultural land. Under this approach, 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 to reflect an overall decline in condition due to human activity.

4.35 A third perspective on ecosystem degradation focuses on the more general question of whether 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 something akin to a previous condition – i.e. the change is irreversible. This approach is not followed in SEEA Experimental Ecosystem Accounting as it does not fit well within a model based on assessment of change over successive accounting periods. Thus, recording ecosystem degradation only at the time where it was known that the situation was irreversible would lack the transparent, ongoing recording of change in ecosystem assets that is one goal in ecosystem accounting.

4.36 It is noted that ecosystem degradation is considered in the SEEA as a distinct concept from depletion of natural resources. Depletion is defined in the SEEA Central Framework 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".[38] The distinction between these two concepts is that depletion relates to the decline in a specific resource while ecosystem degradation relates to the declines 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 takes into account a broader range of characteristics the two concepts should not be equated.

4.37 Overall, while there is a 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 noted that changes in expected ecosystem service flows are likely to reflect both changes in extent and condition but differentiating these effects may be challenging.

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 to restore or remediate an ecosystem asset beyond activities that may simply maintain an ecosystem asset. As 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 implicitly should reflect the ongoing intra-ecosystem flows since it is these flows which underpin the regeneration process. For some purposes it may be useful to explicitly account for certain inter-ecosystem flows 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.

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, noting the existence of thresholds and irreversibilities and varying time horizons. The potential to regenerate means that they may provide the same ecosystem services over an indefinite length of time. Consequently, it is possible over the long term for an ecosystem asset to have no

[38] SEEA Central Framework 5.76. See also SEEA Central Framework Section 5.4.2 for a longer discussion on defining depletion including the links to ecosystem degradation.

ecosystem degradation – i.e. 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, for example due to wetter or drier years. It is noted that from an accounting perspective, even if the intended management of an ecosystem is such that there are ongoing flows of a given level of ecosystem services (e.g. through the sustainable management of fisheries), it should not be assumed that the actual flow of services is equal to the intended level of services.

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 then 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 accrue to the user/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 the way in which the asset contributes to production.

4.46 This standard model provides a strong starting point for ecosystem asset accounting but there are some fundamental differences in the nature of ecosystem assets that require extensions to the standard model to be introduced. 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) new each time.

4.48 Second, a single ecosystem asset may generate varying baskets of ecosystem services over a series of accounting periods. For produced assets, even if a single produced asset may be considered to generate multiple capital services, it is assumed that it 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 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 simply an input into a production function internal to an enterprise that ultimately leads to the production 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. For produced assets their capacity to generate capital services is either fully used or assumed to be at a relatively stable level of use relative to capacity. Permanently underused produced assets are assumed not to be common over a business cycle whereas for ecosystem assets such situations can easily arise.

4.51 These four distinctions require the standard asset accounting model to be adapted for the purposes of accounting for ecosystem assets. These adaptations highlight some, often implicit, assumptions that are made in standard asset accounting that should not be made in an ecosystem asset accounting context.

4.3 Compiling ecosystem asset accounts

4.3.1 Introduction

4.52 Ecosystem asset accounts are intended to organise 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 this section for accounting tables are intended to provide a starting point for experimentation in compilation rather than providing definitive methodological guidance. All of these ecosystem asset tables are designed to give a broad sense of the potential of ecosystem accounting to organise information across a range of areas and from multiple perspectives. It may be useful to consider that these tables reflect a summary of information coming 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 observation is that these tables to do not provide rows or columns related to aggregate measures of ecosystem assets. Defining ecosystem asset aggregates is problematic due to the need to define relationships between the various characteristics. This is discussed in Section 4.3.4. As a matter of compilation practice it is recommended that focus be placed first on the description and measurement of the relevant characteristics before consideration of aggregation.

4.54 From the statistical units model outlined in Chapter 2, the ecosystem accounting unit (EAU) is the most applicable unit for the measurement of ecosystem assets since it should be relatively stable in area over time. However, for the organisation of relevant information, it is likely to be most logical to measure and organise information on the basis of LCEU since the type of characteristics of interest and types of ecosystem service 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, i.e. across multiple EAU and various types of LCEU, 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 and essential in all ecosystems.

4.56 Given the spatial diversity and heterogeneity of ecosystems, ecosystem asset accounts will generally need to be developed in a GIS context. Although the specific datasets 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: (i) land accounts; (ii) carbon accounts; (iii) water accounts; (iv) soil and nutrient accounts; (v) forest accounts; and (vi) biodiversity accounts. A number of these accounts are described in the SEEA Central Framework.

Accounts for assessing ecosystem extent

4.57 To commence the process of assessing ecosystem assets a useful starting point is the organisation 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 shows the physical account for land cover presented in the SEEA Central Framework Chapter 5 (Table 5.6.3). It shows the opening and closing stock of land in hectares for a variety of classes of land cover and 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 2, may take into account factors other than purely 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)[39]

	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	184.5	9 355.5									
Natural expansion			64.5								1.5
Upwards reappraisals			4.5	181.5							
Total additions to stock	184.5	9 355.5	69.0	181.5							1.5
Reductions in stock											
Managed regression			4 704.0	3 118.5	9.0	1 560.0	1.5				
Natural regression					1.5	64.5					
Downwards reappraisals						4.5					
Total reductions in stock			4 704.0	3 118.5	10.5	1 629.0	1.5				
Closing stock	12 477.0	454 786.5	101 545.5	335 577.0	204.0	64 846.5	72.0	1 966.5		12 949.5	19 353.0

Note: Crops includes herbaceous crops, woody crops, and multiple or layered crops.

[39] SEEA Central Framework Table 5.6.3

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

4.59 A potential area of extension concerns the compilation of land cover change accounts. These accounts reconcile estimates of the area of certain land cover types between the beginning and end of an accounting period. The change between land cover types can be organised to highlight particular sources of change and ecosystem conversion such as deforestation, urban expansion, etc. 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 SEEA Central Framework Table 5.6.4), which indicates only the changes in land cover over time rather than considering 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 can be directly measured quantitatively. 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 5 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 (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. 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 is to record inter-ecosystem flows. These entries would require the development of resource accounts that are spatially specific – i.e. relating to a particular EAU or LCEU.

Table 4.2 Physical asset account for water resources (cubic metres)[40]

	Type of water resource						Total
	Surface water				Groundwater	Soil water	
	Artificial reservoirs	Lakes	Rivers and streams	Glaciers, snow and ice			
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 hydro power generation							
for cooling water							
Evaporation & 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

4.63 Note that basic resource accounts do not provide a direct assessment of ecosystem condition. Rather, following an accounting approach, they organise information that is directly relevant to the assessment of various ecosystem characteristics and, as shown below, this information can be combined to provide a basis for an overall assessment of an ecosystem asset.

4.64 While they do not provide a direct assessment, it is the case that tracking stocks and flows of carbon and water across different spatial areas can provide significant insights into changes in ecosystem assets, particularly in terms of providing 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 provide a useful starting point for compilers. This possible starting point is also supported by the generally good availability of data and the presence of guidelines and standards for the compilation of statistics and accounts (e.g. SEEA Water).

4.65 In part using data from basic resource accounts, Table 4.3 provides a broad structure for organising 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 LCEU. The characteristics that are shown are purely illustrative and will apply to the assessment of condition in different types of LCEU to varying degrees. It is recognised, for example, that there may be overlaps between the characteristics of vegetation and biodiversity, but in a systems context such overlaps are inevitable and hence there must be detailed consideration of the relevant bio-physical relationships in the selection of characteristics.

[40] SEEA Central Framework Table 5.11.2

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
	Area	Indicators (e.g. Leaf area index, biomass, mean annual increment)	Indicators (e.g. species richness, relative abundance)	Indicators (e.g. soil organic matter content, soil carbon, groundwater table)	Indicators (e.g. river flow, water quality, fish species)	Indicators (e.g. net carbon balance, primary productivity)
Type of LCEU						
Forest tree cover						
Agricultural land*						
Urban and associated developed areas						
Open wetlands						

* Medium to large fields rainfed herbaceous cropland

4.66 For each characteristic there are likely to be a number of relevant indicators. For example, for water it 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 some 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 powerful, broad indicator for 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 aspects of accounting for carbon.

4.68 The selection of characteristics and associated indicators for the measurement of ecosystem condition should reflect scientifically valid measures. Consequently, to ensure the robustness of the information set it is important that the selection of characteristics and indicators be subject to a scientific accreditation process that can set measurement standards.[41] Such measurement standards are required in order to ensure the integrity of the accounting system. There are a range of relevant considerations in the establishment of scientific accreditation processes and the selection of characteristics and indicators. These are discussed in an annex.

4.69 Each of the indicators included in a table such as Table 4.2 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 4.3.4

Accounting for changes in ecosystem condition

4.70 Within the construct of Table 4.3, which shows indicators of ecosystem condition at a point in time, it may be instructive to compile accounts that show the changes in ecosystem condition

[41] When accounting 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 through the reporting across different variables (sales, profits, wages, etc). Such standard units of measure do not exist across the various physical measures hence the requirement for an accreditation of measurement.

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 for Table 4.3, the indicators used in Table 4.4 are likely to be in different measurement units.

4.71 Determining the estimates of the causes 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 perhaps making distinctions between relatively small, medium and large net changes. This information, for individual indicators, may be effectively presented in maps with colouring coding related to relative size of the changes.

Table 4.4 Changes in ecosystem condition for an LCEU

		Characteristics of ecosystem condition				
		Vegetation	Biodiversity	Soil	Water	Carbon
		Indicators (e.g. Leaf area index, biomass, mean annual increment)	Indicators (e.g. species richness, relative abundance)	Indicators (e.g. soil organic matter content, soil carbon, groundwater table)	Indicators (e.g. river flow, water quality, fish species)	Indicators (e.g. 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 is the measurement of expected ecosystem service flows. Table 4.5 provides a table for recording estimates of expected ecosystem service flows at a point in time for a single EAU. The measurement units are discussed below. No aggregation is presumed and additional rows are required for each ecosystem service under consideration.

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

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

* Medium to large fields rainfed herbaceous cropland

4.73 A key issue on recording entries in this table is that it is likely to be most useful to compile entries in terms of expected flows of ecosystem services per year rather than in terms of absolute quantities.

4.74 In making the estimates of expected flows some allowance should be made for normal year to year variation in flows of ecosystem services for example due to drier or wetter years. The range of factors taken into account in the determination of "normal" may vary from ecosystem to ecosystem and over time.

4.75 The estimates in Table 4.5 rely on measures of ecosystem services and the formation of associated expectations. In turn, estimates of expectations require an understanding of the current mix of ecosystem services and an understanding of the impacts of changes in condition and extent on the ability to provide those ecosystem services in the future in the context of the expected patterns of use and current ecosystem structure. Section 2.4.2 provided some general comments in relation to this issue.

4.76 In addition to these general comments, the following more specific comments in relation to particular ecosystem services are relevant noting that the type of indicators required to reflect the capacity of the ecosystem to supply ecosystem services as a function of ecosystem condition and extent may differ strongly for provisioning, regulating and cultural services.

4.77 For provisioning services, indicators need to reflect both the available stock that can be harvested of the service in question, 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). In turn, the regeneration or growth rate is 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 the specific link between regeneration and overall ecosystem condition is not straightforward, a range of different variables and complex ecosystem processes are generally involved. Since these factors differ 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 in the case of determining capacity to supply timber over time.

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, even though 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, i.e. the total surface area of leaves, expressed in m^2 per hectare (noting that 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 is not necessarily related to the condition of the vegetation.

4.80 Typically the relationship between ecosystem assets and ecosystem services for regulating services often has a spatial aspect. For instance, the ecosystem service air filtration only arises 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) only arises 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 regardless 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 means that the generation of regulation services 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 need to be recorded, as well as the relevant features of the physical or socio-economic 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, depending on which specific ecosystem components or processes are affected. For instance, extinction of a rare, endemic species in a forest may affect cultural services but, unless this species was important for ecosystem functioning (e.g. a non-substitutable pollinator of specific tree species), it would not affect the air filtration (LAI) or the flood protection service provided.

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, presence of walking trails, etc. 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 perhaps to the availability of alternative tourism destinations). Degradation of an ecosystem, or investments in restoration of an ecosystem (reforestation, construction of walking trails, etc.) is reflected in the attractiveness, but not necessarily in the level of actual service provided (i.e. the actual number of visitors).

4.3.3 Aggregation in ecosystem asset accounting

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

4.85 The approaches to the aggregation of expected ecosystem service flows are analogous to the aggregation of ecosystem service flows in a single accounting period as discussed in Chapter 3. The primary difference is that different weighting patterns between ecosystem services may be relevant to account for a changing relative importance of ecosystem services over time that may be incorporated into the estimates of expected service flows, but which is not relevant in the case of a single accounting period. This difference applies even where the expected ecosystem service flows are expressed in terms of rates 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 in terms of hectares or units of carbon. As the number of indicators increases this approach may be less tractable.

4.87 Another approach may be to relate all indicators of ecosystem condition for a given reference condition to a particular point in time. This is part of the second stage in the measurement of ecosystem condition as described earlier in this chapter. While it is possible to use the beginning of the accounting period as a reference condition, for the majority of ecosystem assets, science uses a pre-industrial benchmark to set the reference condition. Relevant examples include the measures of water quality in the European Water Framework Directive and measures of threatened species in the assessment of species biodiversity.

4.88 Following selection of the time of the reference condition, estimates are needed for each indicator for each characteristic at that point in time. When necessary, the values of the indicators at the reference condition may be determined through use of reference sites or through the use of models of biophysical condition. Then all observations in the reference period 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 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 behind the use of the reference condition approach to aggregate within and across ecosystems, the approach requires testing at this scale as it is generally applied for multiple indicators relating to particular characteristics (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 is required in the area of aggregation of ecosystem asset related measures in physical terms. Aggregation for ecosystem accounting in monetary terms is discussed in Chapters 5 and 6.

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 Section 4.3). Such an account would provide indicators of ecosystem condition such as net carbon balance and primary productivity. Carbon accounts can also provide information on the ecosystem services of carbon sequestration and the storage of carbon. This 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 to a wide range of analytical and policy situations. For example, carbon stock accounts can complement the existing flow inventories developed under the UNFCCC (UN Framework Convention for Climate Change) and the Kyoto Protocol. The carbon stock accounts presented here also align with the accounting approach of REDD (Reducing Emissions from Deforestation and Degradation).

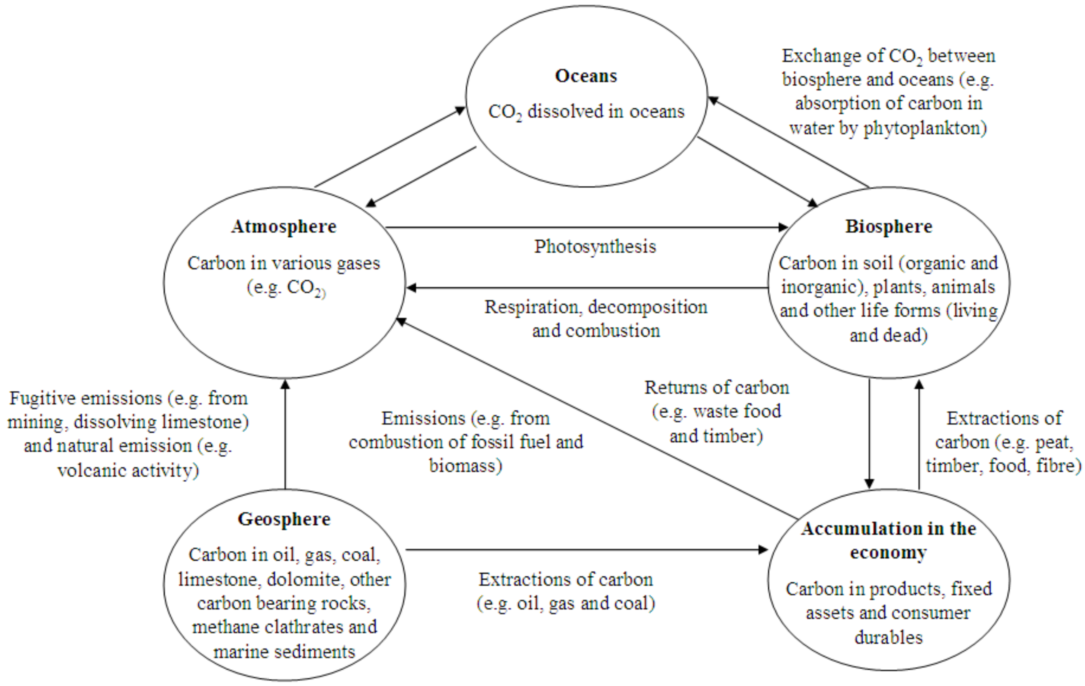
4.93 Carbon stock accounts can provide consistent and comparable information for policies aimed at, for example, protecting and restoring natural ecosystems, i.e. maintaining carbon stocks in the biosphere. Combined with measures of carbon carrying capacity[42] and land use history, biosphere carbon stock accounts can be used to:

- investigate the depletion of carbon stocks due to converting natural ecosystems to other land uses;
- prioritise land for restoration of biological carbon stocks through reforestation, afforestation, revegetation, restoration or improved land management with their differing trade-offs against food, fibre and wood production, and;
- identify land uses that result in temporary carbon removal and storage.

4.94 The extensive role of carbon in the environment and the economy requires a comprehensive approach to measurement. Accounting for carbon must therefore consider stocks and changes in stocks of carbon from the perspectives of the geosphere, the biosphere, the atmosphere, oceans and the economy. Figure 4.1 below presents the main elements of the carbon cycle. It is these stocks and flows that give the underlying context for carbon accounting. Of particular relevance is that there are qualitative differences between the different stores of carbon. Carbon accounting and ecosystem accounting more generally must take these differences into account.

[42] The mass of biocarbon able to be stored in the ecosystem under prevailing environmental conditions and disturbance regimes, but excluding human disturbance (Gupta and Rao 1994).

Figure 4.1. The main elements of the carbon cycle



4.4.2 Carbon stock account

4.95 Applying the SEEA accounting principles of completeness and consistency and the SEEA Central Framework's approach to accounting for residual flows, carbon stock accounts record the stock changes from human activities at any point along the chain: from 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 land fill sites; 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 A structure for 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 the stock or reductions in the stock.

Table 4.6 Carbon stock account

Gigagrams carbon (GgC)	Geocarbon					Biocarbon			Atmosphere	Water in Oceans	Accumulation in economy				TOTAL
	Lime stone	Oil	Gas	Coal	Other	Terrestrial ecosystems	Aquatic ecosystems	Marine ecosystems			Inventories *	Fixed assets	Consumer durables	Waste	
Opening stock															
Additions to stock															
Natural expansion															
Managed expansion															
Discoveries															
Upwards reappraisals															
Reclassifications															
Total additions to stock															
Reductions in stock															
Natural contraction															
Managed contraction															
Downwards reappraisals															
Reclassifications															
Total reductions in stock															
Imports and exports															
Imports															
Exports															
Closing stock															

*Excludes inventories included in biocarbon (e.g. plantation forests, orchards, livestock, etc)

4.97 Carbon stocks are disaggregated to geocarbon (carbon stored in the geosphere) and biocarbon (carbon stored in the biosphere, in living and dead biomass and 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 these are terrestrial, aquatic and marine ecosystems, and these are shown in Table 4.6.

4.98 The different 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 to do so. Different reservoirs therefore have different degrees of effect on atmospheric CO_2 levels (Prentice et al. 2007). Carbon stocks in the geosphere are generally 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 millennia, 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 et al. 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 it is stored in the biosphere that influences the stock of carbon in the atmosphere.

4.101 A key aspect for carbon accounting is to understand the degree of human influence over particular ecosystems. In this it may be desirable to recognise varying degrees of human modification of the ecosystem and potentially introduce these aspects into a classification. Degrees of human modification may be structured to reflect, for example, natural ecosystems, semi-natural ecosystems, and agricultural ecosystems. Details on how these types of ecosystems may be defined are in the annex.

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. 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 the annex.

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 policy makers, 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 where there are significant competing uses of land for food and fibre.

4.104 An indicator that can be derived from the carbon stock account is the ‘net carbon balance’. This indicator relates to 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 other reservoirs.

4.5 Accounting for biodiversity

4.5.1 Introduction

4.105 Biodiversity and its definition in the context of ecosystem accounting has been described 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 would provide information suited for assessing ecosystem condition. This section discusses a possible structure for such an account.

4.106 At both national and sub-national scales, by linking biodiversity accounts with the land cover, land use and the environmental protection expenditure accounts of the SEEA Central Framework, the cost-effectiveness of expenditures on habitat and species conservation or returns on investment may be analysed.

4.107 Using the links to economic accounting in the SEEA, it may be possible to link key drivers and pressures 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 (fisheries and forestry), 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 area lost by conversion. These kinds of integrated analysis will be facilitated if relevant units (e.g. major land cover types, forests, grasslands, etc.) 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 service 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 the species abundance and status. Harvesting in excess of a species’ capacity to regenerate (i.e. unsustainable harvesting) would result in lower yields, reduced economic profit and a higher risk of extinction, and would be reflected in moving to higher risk categories in an account focused on species status.

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

4.110 It should also be recognised that, independently from their use in ecosystem accounting, biodiversity accounts described here and land use and land cover accounts described in the

SEEA Central Framework, can be used to track progress towards 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 where the benefits of use of biodiversity accumulate.

4.111 In this broader context, accounting for biodiversity recognises the importance of biodiversity to people as articulated in several international agreements concerning biodiversity and the conservation of biodiversity. Perhaps the most important is the Convention on Biological Diversity (CBD)[43] which entered into force in 1993. The Convention has three main objectives: (1) the conservation of biological diversity; (2) the sustainable use of the components of biological diversity, and; (3) the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources.

4.5.2 Measurement of biodiversity

4.112 A wide range of techniques are used to measure biodiversity. It is not the intent here to provide a full review of these techniques but 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 complexities of biodiversity measurement a focus is placed on selected indicators of biodiversity rather than accounting of all aspects of biodiversity.

4.113 Biodiversity indicators measure part of the system or capture a range of aspects of the system within single measures. Based on the recommendations of the 9th meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA9) the 7th Conference of the Parties (COP7) agreed on the list of provisional indicators for assessing progress towards the 2010 biodiversity target (COP decision VII/30, 2004)[44] that can be implemented worldwide, or at national or regional scales.

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

(i) Trends in extent of selected ecosystems
(ii) Trend in abundance and distribution of selected species
(iii) Trend in status of threatened species
(iv) Change in genetic diversity

4.115 The first 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 to the reference condition), and the third shows the variability within the mean species abundance, focusing on those species that are threatened. Together these indicators reflect the degree of homogenisation, the core process of biodiversity loss as described in Section 2.1.

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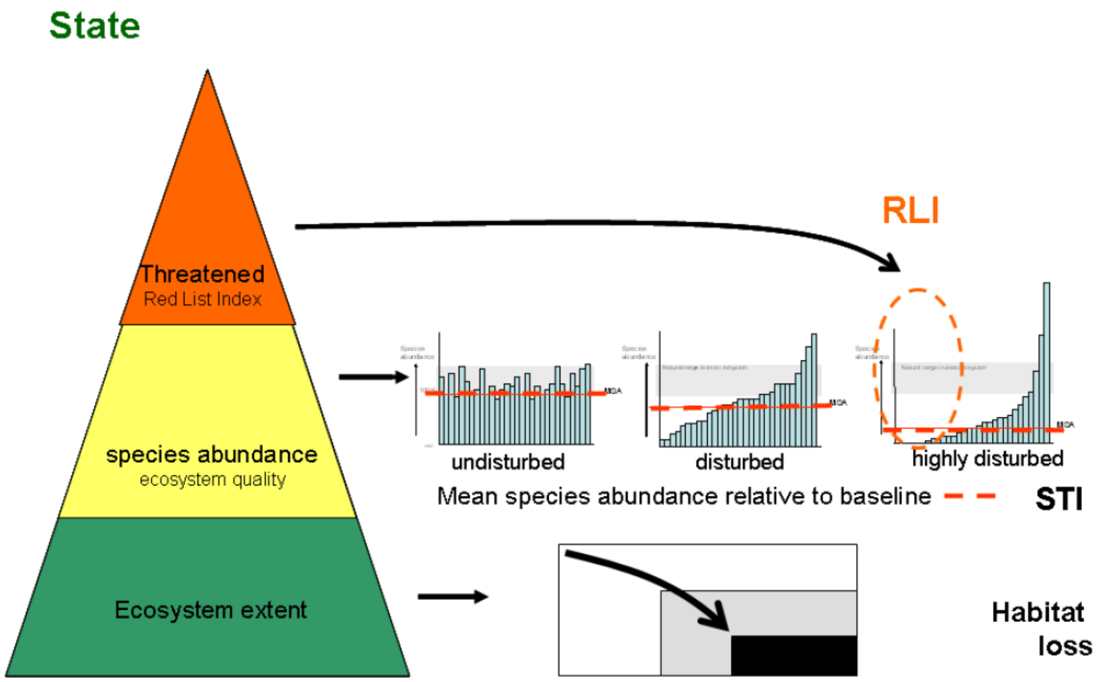
[43] Secretariat of the Convention on Biological Diversity (2003). Convention on Biological Diversity http://www.cbd.int/convention/text/

[44] See http://www.cbd.int/doc/decisions/cop-07-dec-en.pdf

4.116 The figure below summarises the changes in ecosystem, the abundance of species and threat of extinction over time. In this it shows three points in time in terms of habitat extent (the nested squares in the lower right of the diagram). In the middle the consequences in terms change in species abundance are shown, with the red dotted lines showing a composite state index which is calculated referring to a benchmark time (or reference condition). On top, the extinction or close to extinction of some species is indicated by inclusion in the IUCN Red List.

Figure 4.2 Change in ecosystem extent, original species abundance and risk of extinction[45].



4.117 Accounts in physical terms (e.g. hectares) showing the area of different ecosystems in protected areas is a straightforward first step (i.e. using the land cover and land use accounts of the SEEA Central Framework) and these can also be linked to the 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 entire country), since in most countries much of the biodiversity exists outside of protected 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 combine the inter and intra flows in order to combine both the measurements of changes in quality and the measurements of changes of extent in one common evaluation for policy priority purposes. To achieve this both extent and quality measures will have to refer to EAU.

[45] ten Brink, B.J.E., S. Condé, F. Schutyser (2010). Interlinkages between the European biodiversity indicators, improving their information power. Report of the working group on Interlinkages of the Streamlining European Biodiversity Indicators project (SEBI). European Environmental Agency. Copenhagen.

4.119 Biodiversity, as measured by species number and abundance, can be measured directly. However, because this is costly to do for large areas, biodiversity 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.[46].

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 Natural Capital Index[47], the GLOBIO Mean Species Abundance Index[48], the Living Planet Index[49], the Biodiversity Intactness Index[50] and the Norwegian Nature Index[51]. These composite indicators are the result 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 Species can be defined in a range of ways. They are 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). A range of definitions is available but the definition used ultimately depends of the nature of the organism of interest[52]. Species are commonly classified according to the taxonomy established by Linnaeus (1758), which continues to evolve[53].

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 (e.g. the number of different animal species in an area) or richness of endemic species. In this, the species occurring in particular areas are listed as present or absent. These data are more readily available than abundance data (e.g. 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 sub-national scale assessments (biodiversity "hotspots") and, which would detect regional shifts in species distributions and local extinctions.

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[46] Scholes, R.J. and Briggs, R. (2005). A biodiversity intactness index. Nature, 434(3): 45-49. (3 March 2005) Alkemade, R., van Oorschot, M., Miles, L., Nellemann, C., Bakkenes, M. & ten Brink, B. 2009. GLOBIO3: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss 2009. Ecosystems 12:3, 374–390.

[47] ten Brink, B.J.E. and T. Tekelenburg, Biodiversity: how much is left? The Natural Capital Index framework (NCI). in RIVM report 402001014. 2002: Bilthoven.

[48] Alkemade, R., van Oorschot, M., Miles, L., Nellemann, C., Bakkenes, M. & ten Brink, B. 2009. GLOBIO3: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss 2009. Ecosystems 12:3, 374–390. Also see http://www.globio.info/home

[49] Loh, J., et al 2005. The living planet index: using species population time series to track trends in biodiversity. Philosophical Transactions Royal Society, Biological Sciences 360, 289-295, and; Loh, J.,2002. Living Planet Index 2002, World Wildlife Fund International: Gland, Switzerland.

[50] Scholes, R.J. and R. Biggs, 2005. A biodiversity intactness index. Nature. 434(7029): p. 45-49.

[51] Certain, G., O. Skarpaas, J-W. Bjerke, E. Framstad, M. Lindholm, J-E. Nilsen, A. Norderhaug, E. Oug, H-C. Pedersen, A-K. Schartau, G. I. van der Meeren, I. Aslaksen, S. Engen, P.A. Garnåsjordet, P. Kvaløy, M. Lillegård, N. G. Yoccoz, and S. Nybø. 2011. The Nature Index: A General Framework for Synthesizing Knowledge on the State of Biodiversity. PloS ONE 6 no. 4: e18930.

[52] de Queiroz K., 2005. "Ernst Mayr and the modern concept of species". Proc. Natl. Acad. Sci. U.S.A. 102 (Supplement 1): 6600–7. (May 2005). doi:10.1073/pnas.0502030102

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

4.123 At a larger scale, species richness may show little change at a national level, and hence are often difficult to interpret and relate to human activities. Consequently, it may be necessary to augment species richness data with information on the importance of particular species to a region from other sources. For example, by determining whether the species detected in an area are included on 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 only available for a limited number of species. Abundance may be measured in absolute terms such as the total number of individuals of a species or a density per hectare. It can also be measured in broad classes related to absolute measures, for example very abundant, abundant, common, rare, and very rare. Abundance may also be measured in relative terms, in particular 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. Different species exhibit different natural abundances: for example in mammals, small rodents are naturally very abundant, while elephants and other large slow breeding mammals occur in much lower abundances.

4.125 As a precursor to accounts of biodiversity, information on species should be collated in databases. 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 are spatially and temporally (i.e. time period) referenced.

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 may be relatively few, some species are of particular interest, for example because they are harvested for food or have iconic values, and hence accounts may be prepared for these species. Such accounts, for example for fish, are similar to those described in the SEEA Central Framework and are not described further here. Tables for species richness would be of a similar form to the table for species abundance described below.

4.127 Table 4.7 presents the general form of a biodiversity account for species abundance. It may be compiled in both absolute and relative terms of 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 only 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.

4.128 The reference condition of species can refer to any time period, but ideally it should refer to an ecosystem with minimal human influence. Such a baseline can be difficult to establish but this allows the relative abundance of species to be compared between different species, and different ecosystems, within countries and between countries.

4.129 It is important that species from all Kingdoms (i.e. division of living organisms) should be included in the species abundance accounts to ensure the accounts are as representative as possible.[54] However, in practice the species included in the accounts will need to be a

[54] A likely exception is the Kingdom Monera (single cell organisms without a nucleus, e.g. bacteria). These species are not anticipated to be a focus of biodiversity accounting as described here.

representative sample from the Kingdoms as 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.

Table 4.7 Biodiversity account: Species abundance by Kingdom[a] for an EAU

	Animals										
	Mammals	Birds	Reptiles	Amphibians	Insects	Fish	Invertbrates	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											

a The Kingdoms shown in the table are those according to Whittaker 1969. The Kingdom Animals is shown divided by Classes but not all 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 finer levels (e.g. Order, Genus) depending on the availability of data and the information requirements. The Kingdom Monera (single cell organisms without a nucleus e.g. bacteria) is not listed as generally it is not anticipated to be 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 is discussed in Section 4.4. This annex provides some additional details on the structure and accounting entries related to the carbon stock account presented in Table 4.5.

A4.2 The carbon stock account presented in Table 4.6 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 the stock or reductions in the stock.

A4.3 Carbon stocks are disaggregated to geocarbon (carbon stored in the geosphere) and biocarbon (carbon stored in the biosphere, in living and dead biomass and soils). Geocarbon is further disaggregated into: oil; gas; and coal resources (fossil fuels) and rocks and minerals (e.g. carbonate rocks used in cement production, methane clathrates and marine sediments). For accounting purposes where the information generated from the accounts is policy focussed, the priority should be 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 these are terrestrial, aquatic and marine ecosystems, 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 the absence of this, compliers may chose to use the land cover classification of the SEEA Central Framework, noting that the primary purpose of this classification is not for ecosystem accounting, but for understanding production, consumption and accumulation from an economic perspective, not the ecosystem perspective. In this it should also be noted work on land cover classifications is part of the SEEA Central Framework research agenda.

A4.5 A key aspect for carbon accounting is to understand the degree of human influence over particular ecosystems. In this it may be desirable to recognise varying degrees of human modification of the ecosystem and potentially introduce these aspects into a classification. Degrees of human modification may be structured to reflect, 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 which 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 within which human cultural and traditional uses also occur. Natural ecosystems include terrestrial and marine ecosystems.

- Semi natural ecosystems: which are human modified natural ecosystems. Natural processes, including regenerative processes, are still in operation to varying degrees. However, the system is often prevented from reaching ecological maturity or is maintained in a degraded state due to human disturbance and land use. Thus, the vegetation structure may not reflect natural optima, and the taxonomic composition may be depauperate.

- Agricultural ecosystems: which are human designed, engineered and maintained systems on agricultural lands that grow animals and crops mainly for food, wood and fibre and as feedstocks for biofuels and other materials. Plantations of trees for timber or fruit production (e.g. orchards) are included in the agricultural ecosystem. Note that these stocks in the SEEA Central framework and SNA would be included as inventories of the economy and hence must be removed from this category.
- Other ecosystems: including settlements and land with infrastructure.

A4.6 The atmosphere and ocean are the receiving environments for carbon released from primary reservoirs and accumulations in the economy. In this, the atmosphere and oceans may be viewed in a way similar to the way the rest of the world is treated 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 split into shallow and deep ocean reservoirs.

A4.7 Accumulations in economy are the stocks of carbon in anthropogenic products and are further disaggregated into the SNA components: Fixed assets (e.g. concrete in buildings, bitumen in roads); Inventories (e.g. petroleum products in storage, but excluding those include in agricultural ecosystems); Consumer durables (e.g. wood and plastic products); and Waste. Accounting for waste follows the SEEA Central Framework where waste products (e.g. disposed plastic and wood and paper products) stored in a controlled land fill sites are treated as part of the economy.

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

A4.9 Although not shown in the table, these ecosystem types could be disaggregated further into marine and terrestrial ecosystems. Marine ecosystems include mangroves, saltmashes and seagrass beds. Peat stocks and flows align with the biocarbon sector with peatland vegetation associated with a variety of ecosystems, including forests, grasslands, mossbeds, mangroves, saltmashes and paddies. There is potential to disaggregate Geocarbon and Biocarbon further.

A4.10 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. 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: These additions reflect increases in the stock of carbon over an accounting period due to natural growth. This will be effectively only for biocarbon and may arise from climatic variation, ecological factors such as reduction in grazing pressure, and indirect human impacts such as the CO2 fertilisation effect (where higher atmospheric CO2 concentrations cause faster plant growth).

- Managed expansion: These additions reflect increases in the stock of carbon over an accounting period due to human-managed growth. This will be for biocarbon in ecosystems and Accumulations in economy, in inventories, consumer durables, fixed assets and waste stored in controlled land fill sites including the injection of greenhouse gases into the earth.
- Discoveries of new stock: These additions concern the arrival of new resources to a stock and commonly arise through exploration and evaluation. This applies mainly, perhaps exclusively, to geocarbon.
- Upwards reappraisals: These additions reflect changes due to the use of updated information that permits a reassessment of the physical size of the stock. The use of updated information may require the revision of estimates for previous periods to ensure a continuity of time series.
- Reclassifications: Reclassifications of carbon assets will generally occur in situations in which another environmental asset is used for a different purpose, for example increases in carbon in Semi-natural ecosystems by the establishment of a national park on an area used for agriculture would be equalized by an equivalent decrease in Agricultural ecosystems. Here, it is only the land use that has changed; that is, reclassifications may have no impact on the total physical quantity of carbon.
- Imports: A line for imports is shown to enable accounting for imports of produced goods (e.g. petroleum products). Imports are show separately from the other additions so that they are presented with exports.

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

- Natural contraction: These reductions reflect natural, including episodic, 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. Natural contraction also includes losses due to volcanic eruptions, tidal waves and hurricanes.
- Managed contraction: These 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, discarded timber 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.
- Downwards reappraisals: These reductions 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: Reclassifications of carbon assets will generally occur in situations in which another environmental asset is used for a different purpose, for example decreases in carbon in Ecosystems agriculture by the establishment of a national park on an area used for agriculture would be equalized by an equivalent increase in Semi-natural ecosystems. Here it is only the land use that has changed; that is, reclassifications have no impact on the total physical quantity of carbon.
- Exports: A line for exports is shown to enable accounting for exports of produced goods (e.g. petroleum products). Exports are shown separately from the other reductions so that they are presented with imports.
- Catastrophic losses, as defined in the SNA, are not shown as a single entry but are allocated between Managed contraction and Natural contraction. Managed contraction would include fires deliberately lit to reduce the risk of uncontrolled wild fires. Also 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 in the table or a related table.

Annex A4.2 Additional detail concerning accounting for biodiversity

A4.13 A definition and description of biodiversity in the context of ecosystem accounting has been provided in Sections 2.1 and 4.5. Those sections highlighted the strong links between the measurement of biodiversity and ecosystem accounting and explained the potential to develop accounts for species as part of developing indicators of ecosystem condition. This annex provides additional detail 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 compiling 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 are covered in more detail in earlier sections of this chapter and, to the extent that ecosystems are approximated by land cover, the land cover accounts described in the SEEA Central Framework.

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) is a reference to land use but also gives a clear 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 land used for conservation has the express purpose of protecting biodiversity as well as providing opportunities for people to enjoy the environment and the biodiversity within it. Also implicit in this is the 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 categories of protected areas (e.g. according to the IUCN Protected Area Categories[55]) and this has been consolidated in the World Database on Protected Areas[56]. In addition, the Ramsar Convention on Wetlands (1971)[57] currently lists just over 2,000 wetlands of international importance, covering nearly two 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 (i.e. using the land cover and land use accounts of the SEEA Central Framework) and these can also be linked to the 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 entire country), since in most countries much of the biodiversity exists outside of protected areas. The condition of biodiversity, as

[55] For more information see, Guidelines for Applying Protected Area Management Categories, Dudley, N. Ed.(2008): http://data.iucn.org/dbtw-wpd/edocs/PAPS-016.pdf

[56] World Database on Protected Ares: http://www.wdpa.org

[57] The Ramsar Convention on Wetlands. http://www.ramsar.org/cda/en/ramsar-documents-texts-convention-on/main/ramsar/1-31-38%5E20671_4000_0__

measured by species number and abundance can be measured directly. However, because this is costly to do 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.[58].

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 the inter and intra flows in order to combine both the measurements of changes in quality and the measurements of changes of extent in one common evaluation for policy priority purposes. To achieve this both extent and quality measures will have to refer to EAU.

Deriving indices from accounts of species abundance

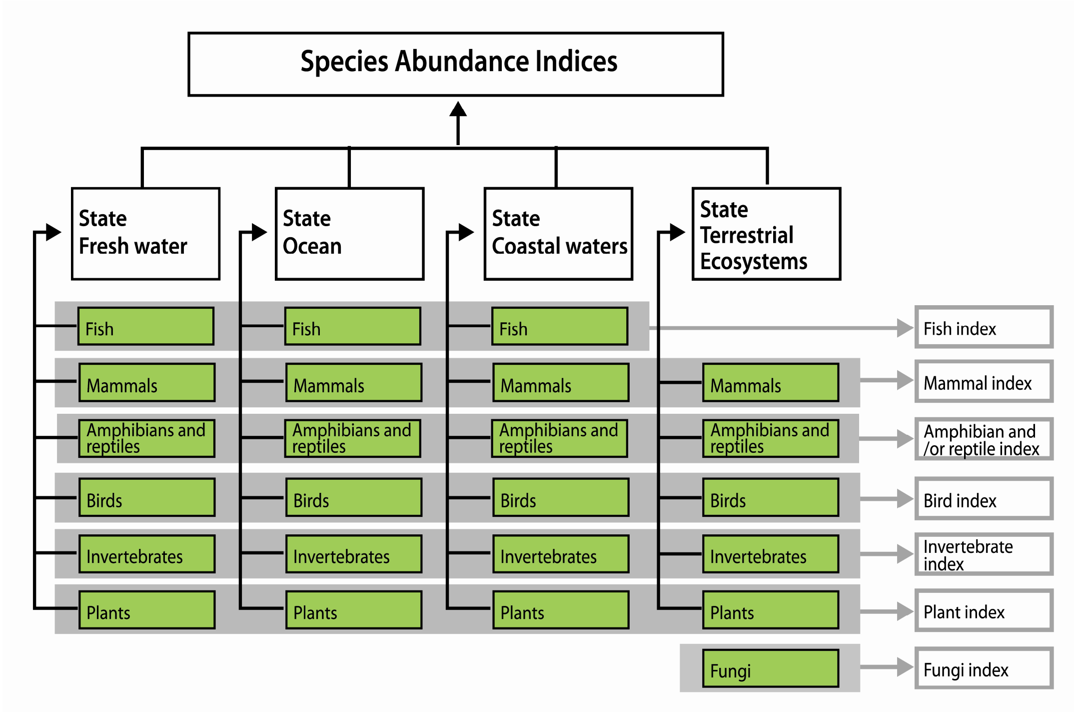
A4.20 The index methods used for economic indicators, such as the consumer price index involving the measurement of changes in a selected basket of goods and services, may provide an approach to constructing species abundance indices from the accounts presented above. The weights used are the average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

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

A4.22 Changes in a total biodiversity index may be explained through a disaggregation into different thematic indices. Figure A4.1 shows how it might be possible to aggregate the measures of species abundance by domain (i.e. freshwater, ocean, coastal or terrestrial ecosystems) or species group (i.e. fish, mammals, etc) to derive an overall index of biodiversity or species abundance index.

[58] Scholes, R.J. and Briggs, R. (2005). A biodiversity intactness index. Nature, 434(3): 45-49. (3 March 2005) Alkemade, R., van Oorschot, M., Miles, L., Nellemann, C., Bakkenes, M. & ten Brink, B. 2009. GLOBIO3: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss 2009. Ecosystems 12:3, 374–390.

Figure A4.1 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, the more widely distributed and abundant and the higher the reproductive rate of a species is, 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[59] take into account these factors and others into account to determine 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 A4.1). These categories are defined as:

- *Extinct* is when there is no reasonable doubt that the last individual of a species has died; *Extinct in the wild* is when a taxon is known to only survive in cultivation, in captivity or as a naturalised population (or populations) well outside the past range;
- *Critically endangered* is when a taxon is considered to be facing an extremely high risk of extinction in the wild;

[59] IUCN-Species Survival Commission, 2001. Red List Categories and Criteria version 3.1. http://www.iucnredlist.org/documents/redlist_cats_crit_en.pdf

- *Endangered* is when a taxon is considered to be facing a very high risk of extinction in the wild;
- *Vulnerable* is when a taxon is considered to be facing a high risk of extinction in the wild; *Near Threatened* is when a taxon is close to qualifying for or is likely to qualify for a threatened category in the near future;
- *Least concern* is when a taxon is widespread and abundant;
- *Data deficient* or *Not evaluated*. Data deficient is 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 is when a taxon has not yet been evaluated against the IUCN threat criteria.

A4.25 It should be noted that 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. It should be noted that the amount of effort needed to prepare the account increases with the number of areas for which accounts are prepared.

A4.27 In national and sub-national accounts is important to note that the status assessments from the IUCN Red List relates to an assessment of the species in the entire world, not to the country and area in question. As such it might be that a species are assessed against different criteria at small scales.

Table A4.1. Accounts for threatened species

	IUCN Red List categories									
	Extinct	Extinct in the wild	Critically endangered	Endangered	Vulnerable	Lower risk	Near threatened	Data deficient or not evaluated	Least concern	TOTAL
Opening stock										
Additions										
- from lower threat categories										
- from higher 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 categories										
- reclassifications										
- local extinction										
- updated assessments										
Total reductions										
Closing stock										

V: Approaches to valuation for ecosystem services and ecosystem assets

5.1 Introduction

5.1 The valuation of ecosystem services and ecosystem assets is complex. In a purely accounting context, the complexity exists because generally, ecosystem services and ecosystem assets are not traded on markets in the same way as other goods, services and assets. As a consequence, 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 and the value of the environment and ecosystems may be discussed and evaluated in non-monetary terms. Consequently, attempts to place values in monetary terms on ecosystems may be considered inappropriate and potentially misleading. Notwithstanding these concerns, there are many projects and considerable interest in the valuation of ecosystem services and ecosystem assets in monetary terms. Given this background, decisions to undertake the valuation of ecosystems and the estimated valuations themselves commonly generate the most contention among all measurement issues.

5.3 Often there is a general lack of understanding of the technical and practical complexities involved in valuation, particularly as they pertain to valuation in an economic accounting context. Consequently, the ambition in this chapter is to outline (i) the various motivations for valuation in monetary terms, (ii) the different valuation concepts and principles that may be applied, (iii) the SNA valuation principles that are relevant when the intent in valuation is to compare ecosystem valuations with existing national accounts valuations; and (iv) the range of possible valuation methods and associated measurement challenges. A specific objective of the chapter is to enable compilers and analysts of ecosystem accounts to make decisions regarding valuation while being aware of the required assumptions and of the 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 depending 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 utilised without a more careful consideration of the relationship between the purpose of analysis and the choice of valuation concepts and methods. This section describes the key aspects that should be taken into account in determining whether to undertake valuation and what concepts and methods can be applied.

5.5 For many, there is interest in the analysis of specific policy scenarios and alternatives, in the evaluation of specific projects, for example in cost-benefit analysis, and in the assessment of compensation and damage claims. For others, there is interest in estimating valuations of ecosystem services and assets that can be used to make comparisons with valuations presented in the standard national accounts or possibly to augment the standard national accounts using alternative measurement boundaries. Examples of these comparisons include comparing the values of environmental assets (including ecosystems) with other asset types (e.g. produced assets), and determining the contribution of ecosystem services to measures of economic activity. There is also a general motivation of raising 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 alternatives. Usually, in decisions made by governments at all levels, the assessments of costs and benefits take into account not only the impacts 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 straightforward to estimate from market-based valuations, the social and environmental aspects are typically more challenging to value. Nonetheless, for the purposes of assessing specific policy choices (such as where to build a hospital, whether to install lighthouses, or whether to restore polluted wetlands) it is relevant to estimate the relevant costs and benefits taking into account these social and environmental aspects and hence additional valuation strategies are needed.

5.7 Additional valuation strategies are also needed where comparison with, or augmentation of, standard national accounting estimates is the motivation for valuation. In this case, an important starting point is the recognition 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).[60] The valuation focus is thus 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 in the SNA.

5.9 There are important implications linking the specific motivations with the type of valuation concept to be used. In broad terms there are two related but different valuation concepts. The first, referred to here as welfare economic values, relates to obtaining valuations that measure the change in the overall costs and benefits associated with ecosystem services and assets. The second, referred to here as exchange values, relates to 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 differences between the valuations estimated using the different concepts, it is important that the motivation 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, depending on the method, it may be possible to estimate different

[60] See 2008 SNA, 2.23.

valuation concepts using the same approach. Thus, it is not only the choice of concept and the choice of method that must be considered but also the way in which the method is applied.

5.11 The remainder of this chapter examines the following issues. Section 5.3 discusses alternative valuation concepts. Section 5.4 discusses the valuation principles of the SNA. Section 5.5 describes a range of approaches to valuation and their application to the measurement of the alternative valuation concepts. Finally, Section 5.6 presents some particular measurement issues that should be considered in undertaking valuation of ecosystem services and ecosystem assets. Of particular note in Section 5.6 is a discussion of uncertainty in valuation which notes four key sources of uncertainty that impact on valuation exercises.

5.12 Since the focus of valuation in SEEA Experimental Ecosystem Accounting is on valuations that permit comparison with and augmentation of valuations in the SNA, the discussion does not extend to a complete articulation of all matters pertaining to the valuation of ecosystem assets and ecosystem services. Rather, the intent 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 recognised that for other purposes alternative choices of valuation concept and valuation approach may be more appropriate. In particular, for policy assessment and evaluation it is likely that the purpose of valuation will be welfare analysis and hence 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 approaches may vary depending on the purpose of the analysis, the broad targets of valuation – ecosystem services and ecosystem assets – remain the same. Thus while the focus of valuation for ecosystem accounting described here may not suit all purposes, ecosystem accounting in physical terms as described in Chapters 3 and 4 is relevant in all situations, and the accounting model described in Chapter 2 provides a coherent and integrated framework for ecosystem assessment whatever valuation concept may be 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 assets in terms of their contribution to either (i) the value that accrues to individuals (private goods) or (ii) the value that accrues to society more broadly (public goods). Because of the different characteristics of private and public goods, different approaches to the estimation of relevant prices must be considered.

5.16 Provisioning services are typically private goods whereas many regulating and cultural services have a public goods character. Public goods involve the conditions of (i) non-excludability, meaning that is not possible to deny people the benefit from the ecosystem service, and (ii) 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. Eco-tourism can be seen as a 'quasi' public good, to a degree it is non-rivalrous (assuming no over-crowding), but in principle it is excludable (e.g. by placing a fence around a particular site and charging entrance fees). Depending on the regulatory system, fisheries and forests which 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 for others) but are often not excludable.

5.17 Therefore, the price mechanism for the provision of public goods does not function well: 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 to maintain or create an efficient allocation of such goods. Because public goods are not traded in a market, 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

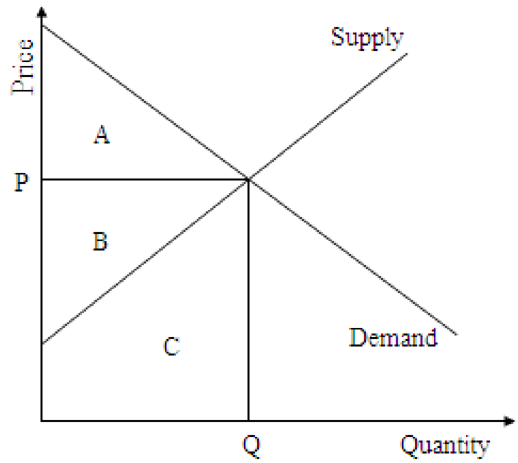
5.18 In neo-classical welfare economics, the value of a good or service is determined by the demand for and supply of that good or service in a perfectly functioning market. This is illustrated in Figure 5.1. This figure shows a demand and a supply curve for a good traded in a market in quantity ‘Q’ 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 less than the highest price they would be willing to pay.[61] The producer surplus, depicted by ‘B’, is the amount that producers benefit by selling at a market price that is higher than the least that they would be willing to sell for, which is related to their production costs. The 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 labelled the ‘surplus’. The surplus can be seen as the net economic gain resulting from market transactions with a volume of 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 occurred if the services had been freely traded and exchanged. This market price, equivalent to price P in Figure 5.1, reflects consumers’ marginal willingness to pay for the ecosystem service at the market equilibrium quantity of services Q. In the case of ecosystem services not traded in a market, alternative approaches to establish a price for the ecosystem, in line with the SNA accounting principles, need to be found, as further discussed in Section 5.5.

[61] It is noted that a distinction exists between individual and aggregate consumer surplus.

Figure 5.1 Consumer and producer surplus



5.21 For national accounting purposes, the focus of valuation is on the area of producer surplus plus costs of production, i.e. areas B and C. This reflects a concept of exchange value in which, 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 the area B plus C, or equivalently, is equal 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.

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. Then it evaluates 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 (potentially infinite) the estimate of consumer surplus becomes.

5.23 Following this characterisation, 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, is 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 discussion on approaches to valuation therefore considers the extent to which consumer surplus is incorporated in the resulting analysis. A critical aspect here is that willingness to pay measures that are commonly estimated and reported in the literature apply some approaches to the valuation of ecosystem services that do not solely reflect a constructed market price reflecting exchange values, but also include 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, scarcity) associated with the good or service. Thus, shadow prices are not observable in the market.

5.25 In the context of welfare analysis, shadow prices are theoretically useful to assess 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 via a market mechanism. Rather, they are marginal in the sense of reflecting the change in welfare associated with a marginal change in the relevant good or service.

Total Economic Value

5.27 Demand curves, such as shown in Figure 5.1, reflect that different consumers are willing to pay different amounts for different quantities of a particular good or services. 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 aspects 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 may be 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 framework. In the TEV framework the value of a good or services is considered to be composed of four key aspects:

i. <u>Direct use value</u> arises from the direct utilisation of ecosystems, for example through the sale or consumption of a piece of fruit.

ii. <u>Indirect use value</u> stems from the indirect utilization of ecosystems, in particular through the positive externalities that ecosystems provide, for example clean air.

iii. <u>Option values</u> relate 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. placing a value on a forest reflecting the potential to find plants for medicinal purposes) or they may be willing to pay now for insurance against possible future losses.

iv. Non-use value is derived from attributes inherent to 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 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, focus is on welfare economic values and the use of welfare analysis, since it is the impact of various policy choices on economic outcomes that are of common interest. This alignment between motivation for valuation and choice of 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 appropriate to use a consistent valuation basis for all entries. Since accounting uses as its basis 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 summarises 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 using welfare economic concepts of value. However, this is likely to require a re-estimation of relevant, SNA based, accounting valuations 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 often market prices (based on exchange value concepts) are used as proxies for shadow prices.[62]

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 2, 3, and 4 explain in detail the relevant concepts and the various approaches

[62] See for example UNEP (2012) Inclusive Wealth Report. A particular focus in this report is the potential inclusion 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.

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 of the market price that is attributable to other inputs including capital and labour.

5.34 Other ecosystem services contribute to non-SNA benefits. For example, various regulating services generate clean air. For these services there is no market price for the benefit that can be partitioned and hence 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 of all of the ecosystem services within a given spatial area (e.g. for a given 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, and hence, following standard approaches to capital accounting, provide an estimate of the overall value of ecosystem assets. Each type of aggregation requires particular assumptions and involves distinct measurement challenges. Consequently, there may not be interest in compiling all of the potential monetary measures even though they may be conceptually possible. 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 that are complex assets, have the potential to regenerate over time, provide multiple services, and may have varying degrees of use over time. A related question is whether the valuation of ecosystem degradation should be based on analysing foregone 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 is discussed further in Chapter 6.

5.4 Valuation principles in the SEEA and the 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, 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”. (2008 SNA, 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 and subsidies and as a result of 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 – each defined by different treatments of taxes, subsidies and margins. The distinctions between these different prices should be considered in valuation exercises but they 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 Following SNA, a transaction is an economic flow that is an interaction between institutional units (e.g. between corporations, households, governments) by mutual agreement or an action within an institutional unit that is analytically useful to treat like a transaction – for example household own-account production. (2008 SNA, 3.51) A large proportion of transactions are monetary transactions in which one institutional unit makes a payment (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 indirectly measured or otherwise estimated. In some cases a non-monetary transaction may be clearly observed between institutional units, for example barter transactions, and for national accounting purposes, a value should be estimated to record it in the accounts. In other cases, the entire transaction must be constructed and then a value estimated for it. These constructed transactions are referred to as imputed transactions. (2008 SNA, 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 one that 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 relevant to note two usually unstated assumptions. First, it is assumed 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 inter-related effects. Second, it is assumed that the prices being used to approximate the missing prices are themselves formed in a manner that can be considered incentive compatible[63]. That is, the market/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 – the cost of production approach - to be used in which the value of the non-monetary transaction is equal to the sum of the costs of producing the good or service, i.e. 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, 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.[64] This approach to estimating prices effectively reflects a decomposition of the concept of a market price that is amenable to estimation, since the components are observable. In relation to Figure 5.1 this method measures area C where it is assumed that the costs of production include a normal return on capital – i.e. there is no producer surplus in the production of these outputs.[65]

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, 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, 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 both a value for the dwelling (or buildings) on a piece of land as well as a value for the land itself (in particular its size and location). The notion of composite assets is one that is explained further in SEEA Central Framework Section 5.6 and is of relevance in the context of ecosystems which, by definition, represent a combination of bio-physical 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. There are two main approaches that are described in the SNA to deal with this situation.

5.50 The first approach is to use the written down replacement cost which recognises that the value of an existing asset (primarily produced assets) at any given point in its life, is equal to the

[63] 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.

[64] Strictly, 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).

[65] For non-market output of government the costs of production are defined to exclude the net return on capital component (see 2008 SNA 6.125)

current acquisition price of an equivalent new asset less the accumulated consumption of fixed capital on the existing asset over its life. (2008 SNA, 13.23)

5.51 The second approach is to use 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 approach – or NPV – uses projections of the future returns from the use (usually extraction or harvest) of the asset. The SEEA Central Framework discusses NPV approaches at length in Chapter 5 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 that in turn gives 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 aspect of accounting. One way of considering changes in value is to recognise that changes may arise due to changes in prices or changes in quantity. For national accounting purposes, the decomposition of value into price and quantity components is undertaken with an index number framework. This framework also provides the basis for the direct measurement of price change (for example, the Consumer Price Index). Index number theory is well established but, at the same time, there are a number of choices that can be made in undertaking any decomposition of values.

5.54 A key issue is that items being valued will generally change in quality over time. For example, a new car purchased in 1990 is likely to be quite different in quality from one 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. One of these approaches is known as a hedonic approach and relies on breaking up an item into its various “characteristics”. Assessment of the change in each of the characteristics is then aggregated to form an overall assessment of whether the total value (i.e. purchase price) of an item 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 The appropriate valuation approach differs by type of ecosystem service since different ecosystem services contribute to economic and other human activity link to benefits and wellbeing in different ways. Consequently, in order to design a valuation approach for a specific ecosystem service, it is necessary to understand (i) how the service leads to the generation of benefits, and (ii) the relation between these benefits and the recording of the related economic activity in SNA.

5.57 In this context it is relevant to note that where a link to the SNA can be made, i.e. an ecosystem service can be linked to the value of output of an SNA product, valuation approaches tend to focus on determining the contribution of the ecosystem service to the market price of the product rather than valuing the ecosystem service directly. These situations 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 are a significant challenge and also have their own conceptual limitations that are discussed in the following sections.

5.58 The following sections describe some general economic considerations that apply to each of the different broad types of ecosystem services and then discuss specific approaches that have been developed for the valuation of quantities of ecosystem services.

Provisioning services

5.59 Provisioning services relate to goods extracted from or harvested in an ecosystem and 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 deriving the valuation of the relevant ecosystem service. It is also noted that there may be significant impacts from taxes and subsidies on production that also need to be considered.

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

5.61 The collection of food or raw materials may take place in an ecosystem unaffected by human activity, but is more likely that harvesting and extraction occurs in an ecosystem that is modified by people. This modification may be in the form of enrichment planting of specific species or reflect degradation because of past overharvesting. Many ecosystems have been modified to favour the supply of specific services, as in the case of 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. There may be private ownership of the ecosystem, with the land owner 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. 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 the way in which the costs of maintaining ecosystem services supply are reflected in the relevant economic transactions.

5.63 In the case of a private land owner harvesting timber or crops from an ecosystem, the owner is likely to have used labour and produced assets to modify the ecosystem, and to harvest the resource. The supply curve, and in particular area C in Figure 5.1, thus reflects the costs involved in harvesting (labour, produced assets (via 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, 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 that are used by the land user. However, it needs to be kept in mind that the value of land may reflect several other important factors, for instance speculation on potential increase in future land value due to land development (for instance when farm land 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 is the collection of berries on government owned land, or fishing in waters that are not regulated or not requiring the purchase of a fishing license. 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 considerations in adopting a resource rent approach that are further analysed below.

5.66 Note that one ecosystem can supply different types of provisioning services, for instance timber benefits from a forest plot may accrue to the land owner, but the collection of mushrooms and berries on the same plot may be free to the public and under an open access regime. This highlights the need to consider the valuation of different types of provisioning services separately.

Regulating services

5.67 For regulating services, the overall valuation context is somewhat more difficult. Regulating services allow economic activities by means of the positive externalities they generate. For instance, an ecosystem providing flood protection services allows the safe habitation, or agricultural activities, in a zone otherwise prone to flooding. Where these services directly affect human well-being, as in the case of 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 avoiding damages to production. For example, flood protection services may allow agricultural production in flood plains. 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 payment mechanisms for ecosystem services (PES) have been set up. In cases without PES, these services are normally part of the producer surplus, reflecting that as a consequence of the regulating services some producers have more favourable conditions for specific economic activities than other producers, or that they are not required to take mitigation measures (e.g. construct flood control structures).

5.69 In cases where the costs of mitigation or adaptation are higher than the producer surplus, as in the case where mechanical flood protection is very expensive, the producer is likely to cease activities when the regulating services provided by the ecosystem are no longer provided. In this situation, the producer surplus (area B in Figure 5.1) represents an estimate of the maximum amount that a producer would pay for the services and thus may be considered a reasonable upper bound on the value to the producer of the ecosystem service. However, it should be recognised that the producer surplus will, in most cases, not only reflect the services provided by ecosystems but also other factors (e.g. distance to market, technology) that facilitate production at lower cost than competitors.

5.70 For the valuation of regulating services, in the absence of markets for ecosystem services, there is a need to reveal the marginal willingness to pay of consumers for the service involved – with consumers in this case including for instance agricultural and industrial producers. Commonly, the focus of measurement for regulating services is welfare analysis and hence the application of a number of the valuation methods developed in the field of environmental economics includes elements of consumer surplus. Without adjustment, these estimates may be less applicable in the context of estimating exchange values for comparison with standard economic accounting estimates. A notable exception is the replacement cost approach. This method is of particular relevance to the valuation of regulating services, and is further described below.

Cultural services

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

5.72 On the other hand, cultural services related to tourism and recreation are somewhat different in that they provide both a consumer surplus and a producer surplus. Generally, the economic activities in 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 singled out in this context. This contribution differs strongly between different activities (it may normally be smaller for a restaurant than say a canoe rental firm) – but will also vary between individual firms. For instance, a hotel located adjacent to a national park may attract tourists in particular because of the possibilities for ecotourism, which may not be the case for a hotel in a city centre.

5.73 In order to analyse the monetary value of the ecosystem services for recreation and tourism, it is therefore necessary to estimate the relative importance of recreational and experiential activities within ecosystems in determining the number of tourists who visit certain areas. Finally, it is 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 in 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 In the following paragraphs a range of approaches to pricing ecosystem services are described. 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 is being measured and the relevant assumptions such that the approach used is appropriate to the intended valuation concept and purpose of valuation.

5.75 In this context the following general remarks are relevant. First, most approaches to the valuation of ecosystem services focus on the measurement of the direct and indirect use values with relatively fewer studies including the non-use and option 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 estimate a demand curve for a particular service and from this demand curve it may be possible to determine an appropriate estimate of exchange values.

5.77 Third, depending on the valuation approach and design of the valuation study, the valuation approaches described in this section may not take full account of the negative impacts of economic and other human activity on ecosystem assets, i.e. ecosystem degradation. For example, use of resource rents to estimate value may make the assumption 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. restoration cost, value of ecosystem resilience, some revealed preference studies) but more research is needed to either (i) combine these approaches which reflect assumptions regarding future degradation, with approaches used to value the current level of ecosystem services; or (ii) 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 such as those related to outputs of the agriculture, forestry and fishing industries, in particular where there are no or limited possibilities to use land leases and prices as an indicator for the price of ecosystem services. In the case of provisioning services there is usually a measureable 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 3 provide an indication of the types of considerations that are needed in defining the links between benefits and ecosystem services for a range of provisioning services.

5.80 Importantly, given the use of human inputs, the price of the benefit, e.g. the price of landed fish, should not be used directly as a surrogate price for the ecosystem service. That is, some of the benefit price reflects the costs of labour and produced assets. The difference between the unit costs of labour and assets and the benefit price represents 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 accurately reflect a price for the ecosystem services that takes into account the potential for degradation of the resource. These conditions include that the resource is extracted / harvested in a sustainable way and that the owner of the resource seeks to maximise their resource rent.

5.82 Often, these conditions are not met. In particular, if there is open access to the resources and no charging of access by the owner, then the marginal unit resource rent tend to zero thus implying that the price of the ecosystem service is zero. Thus depending on the access conditions in place the resource rent approach to valuing marketed ecosystem services may not be appropriate.[66]

5.83 Although the analysis of resource rent is a well established area of economics, a review of the available methods suggests that there is a general need to develop alternative approaches to analyse the value of ecosystem services in the case of open access resource management.

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 would be lost, as in the case of constructing a water purification plant if the water filtration service of an ecosystem supplying groundwater to an aquifer used for drinking water is impaired. This method does not involve any consumer surplus, and is based on the assumption that society would indeed chose to replace the service if it would be lost. Literature states that this method can be used, in principle, in case the alternative considered provides the same services, is the least-cost alternative, and if it can be reasonably assumed that society would chose to replace the ecosystem service if 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 these sediments can be used as an indication of the value of the service, under the

[66] It is noted that there are no ecosystem services associated with the extraction of non-renewable natural resources, such as mineral and energy resources, and hence the valuation of these resources are not discussed here. See the SEEA Central Framework, Chapter 5 for details on the valuation of non-renewable resources.

same conditions of being an adequate and least-cost treatment, and it being likely that society would chose to conduct the treatment if the damage occurs.

5.87 It is noted that these two methods differ from other "cost" methods such as avoidance costs and restoration costs. A particular feature of the replacement cost and costs of treatment methods is that they aim to estimate the price for a single ecosystem service rather than considering a basket of ecosystem services.

Payments for ecosystem services and trading schemes

5.88 There is increasing experience in establishing markets for regulating services, in particular for carbon sequestration, but to a smaller degree also for hydrological services, in particular the regulation of water flows (flood mitigation) and control of sedimentation. For carbon, there are a range of different markets operating in different parts of the world with a different degree of maturity and market turn-over. 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 that relate to 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 these settings.

5.89 Carbon sequestered in ecosystems is mainly traded in voluntary carbon markets. Such carbon markets are rapidly evolving. A scheme in New Zealand permits the trading of credits from forest carbon in a compliance scheme, but so far only small quantities of forest carbon have been traded.

5.90 To date, most market transactions on forest carbon concern 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 REDD (Reduced Emissions from Deforestation and forest Degradation) have been started. These projects sell carbon credits from reduced carbon emissions to the atmosphere generated by activities aiming to reduce deforestation and/or degradation, hence to maintain the storage of carbon in an ecosystem. Payments are made, in the case of REDD, for reducing emissions compared to a baseline case representing business as usual emission rates, i.e. with no REDD project in place.

5.91 The market for both the sequestration and storage of carbon in ecosystems is reflected in the way carbon services are defined for SEEA Experimental Ecosystem Accounting (see Chapter 3). In order to establish a price for carbon, a first estimate may be based on the price raised 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 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, programs that channel development impact fees and offset policies. A limited number of biodiversity markets have been set up that fulfil the basic characteristics of a market: (i) the presence of buyers and sellers; (ii) a traded unit, reflecting biodiversity; (iii) a market clearing mechanism in which a price is established; and (iv) an institutional setting regulating the market and ensuring compliance. The traded unit in these markets are commonly credits related to species or to acreage of habitat conserved.

5.93 Examples of emerging biodiversity markets are (i) Conservation Auctions in Victoria, Australia; (ii) BioBanking, New South Wales, Australia; and (iii) Conservation banking (US). These schemes allow establishing a surrogate market price 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 that it cannot easily be translated to the value 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 is needed 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 are incentive compatible.[67] 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 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 the hedonic pricing, production function, travel cost, and averting behaviour methods as described below. Rather than replying on behaviour exhibited in existing markets, stated preference methods depend on questionnaires of 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 is therefore needed 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 of the revealed and stated preference methods rely on some construction of a market demand curve or use of an existing market with an underlying utility function. Consequently, there is the potential that with further analysis of the models from an exchange value rather than welfare economic value perspective, these approaches may provide data or functions for use in developing estimates of exchange values for use in ecosystem accounting.

[67] 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.

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 principle, i.e. disentangling the contribution from the ecosystem versus contributions from other production factors, is analogous to the use of 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 market product, for example the link between the preservation of a wetland and 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 the storm and flood protection service, by disentangling their contribution to the generation of outputs traded in a market.

5.99 Hedonic pricing methods analyse how environmental qualities affects the price people pay for market products or assets. For example, hedonic pricing can be applied to reveal the value of local ecosystem services that contribute to the value of a property, as in the case of urban green space increasing 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, etc.), other factors, and local ecosystem services.

5.100 Hedonic valuation methods may also be used in valuing ecosystem assets, for example, forests, where 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 where there are possibilities to alter the use of an ecosystem asset in the future. The application of hedonic valuation analysis requires a sufficiently large amount of data to permit statistical identification of the relevant characteristics of the land areas to be captured, including the availability of ecosystem services.

5.101 Averting behaviour methods are used as an indirect method to evaluate 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. It is necessary for households to be fully aware of the impacts on them resulting from environmental changes in order for this method to be applicable. However, due to lack of information, short-term focused behaviour and the complexity of assessment, the averting behaviour method will often underestimate the value of the service as people may not be aware of environmental concern or may be 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 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 present difficulty in determining the value placed on an ecosystem service or the condition of a service provided at a site unless the study is conducted over time and the service and/or condition varies over time. Multi-site models employ a random utility framework that 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, the studies using travel cost methods focus on estimating total willingness to pay and hence the valuations incorporate measurement of some of the consumer surplus generated for visitors to ecosystems. Depending on the methods used it may be possible to derive estimates from these studies consistent with exchange values or to establish studies that are 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 a 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. Choice experiments ask respondents 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 valuing 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 a credible case for a potential payment for an ecosystem service. Econometric procedures can then be used to reveal 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 the 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 eliciting 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 stated willingness-to-pay for the ecosystem as a whole. In addition, contingent valuation measures may overestimate economic values if respondents do not believe 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). Studies using these methods typically produce estimates of consumer surplus and thus 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 can be used to derive a demand curve representing the willingness to pay for particular ecosystem services (e.g. travel cost method, averting behaviour method). Consistent with the discussion on valuation concepts in Section 5.3, a possible step in the estimation of exchange values is 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 curve would provide an estimated market price, from hypothetical market. Alternatively, 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 Spanish economists in the specific context of accounting in the forestry sector. The approach aims to measure the income that would occur in a hypothetical market where ecosystem services were bought and sold. It involves estimating a demand 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-maximising resource manager under alternative 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. The Simulate Exchange Value approach estimates the value of ecosystem services in terms of potential revenue and can therefore arguably represent a more consistent basis for including 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 relation between the 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. In a watershed with an initially high forest cover, the different plots have a low marginal value related to flood control: conversion of one or 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 prices of regulating services will normally be variable over time as a function of the state of the ecosystem.

5.111 The value of the regulating services will also vary over time as a function of economic development: the more people who live in an area and have their economic activity (including consumption) supported directly or indirectly by the regulating service, the higher the value of the regulating service. In the most extreme case, if no one is living in the area where potential benefits of the regulating service arise, the exchange value of a service may be zero. To reflect these population and demand changes, estimates for the value of regulating services will need to be updated for every accounting cycle.

5.6.2 Aggregation

5.112 For the purposes of ecosystem accounting, the consideration of valuation must go beyond determining appropriate approaches to the estimation of prices and value for individual ecosystem service flows. To integrate monetary estimates of ecosystem services within broader accounting frameworks it is necessary to undertake aggregation. Aggregation itself must be considered from a number of different perspectives: (i) aggregation of the value of different ecosystem services within a single ecosystem; (ii) aggregation of the value of ecosystem services across multiple ecosystems; and (iii) aggregation of the value of expected ecosystem services flows to provide an estimate of the value of an ecosystem asset. Each potential aggregation is considered in turn. It is 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 considered at a larger scale.

Aggregation within a single ecosystem

5.113 Assuming that valuation of ecosystem services is possible, in concept the logic in aggregation here is akin to 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 value (price times quantity generated) for each ecosystem service. This may be able to be used to compare the value of ecosystem services provided by different ecosystems and also allows the relative value of different ecosystem services within an ecosystem to be compared.

5.114 While simple in concept, this approach assumes that each ecosystem service is independent or that 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 there is the potential to double count the contributions of individual ecosystem services. Resolution of these issues is likely to require a thorough understanding of the relevant ecosystem processes in physical / scientific terms and understanding of the contributions of ecosystem services to human wellbeing. Ongoing research into bundling and stacking issues in ecosystem service measurement may provide guidance in advancing this aggregation issue.

5.115 Aggregation within an ecosystem may be complicated through the use of different methods of pricing for different ecosystem services since the overall valuation basis may become more difficult to determine. Nonetheless, to the extent that each method used applies the same valuation basis, e.g. market prices, then the extent of this complication may be more limited.

5.116 It is observed that the meaningfulness of the resulting sum of values of different ecosystem services depends on the coverage of the measured ecosystem services. In cases where the measured ecosystem services do not provide a relatively complete coverage of the set of ecosystem services then the overall value will be of limited usefulness. In this regard, the comprehensive measurement of ecosystem service flows in physical terms is an important starting point.

5.117 Finally, the meaningfulness of the sum of values will be affected by the consistency in approaches to valuation of individual ecosystem services. Certainly, where different approaches provide estimates relating to different valuation concepts (i.e. exchange value or welfare economic value), the resulting aggregates will be difficult to interpret. However, even in cases where a consistent valuation concept is applied, the use of different measurement approaches for different ecosystem services may still lead to gaps and overlaps in valuation that need to be considered.

Aggregation across ecosystems

5.118 Aggregation across ecosystems, for single or multiple ecosystem services, encounters the same issues outlined above and the additional challenge of value transfer, 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 a single ecosystem to estimate values in another similar ecosystem after adjusting for various characteristics such as size, proximity to population centres, etc. Value transfer is discussed further in the following sub-section.

5.119 As the range of ecosystem types increases and as the number of ecosystems and ecosystem services analysed increases, the aggregation issues will become more complex. Depending on the analytical questions under investigation this step 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). This type of aggregation is likely to still require rules appropriate to the service measured (e.g. summary, averaging, pro-rating) and the use of value transfer methods but the focus on a single ecosystem service limits the impact of issues that arise in the aggregation of different types of ecosystem services.

Aggregation to create values for ecosystem assets

5.120 For certain purposes it may be relevant to compile measures of the value, in monetary terms, of ecosystem assets. The motivations and limitations of undertaking this compilation are discussed at some length in Chapter 6. For the purposes of discussion here, the starting point in estimating aggregate values of ecosystem assets is that the expected future flows of each ecosystem service can be valued and then discounted to the current period. This derives a Net Present Value (NPV) based estimate of ecosystem assets and follows the same accounting logic as applied in standard asset accounting.

5.121 The measurement of NPV based estimates of ecosystem assets raises a number of challenges. These include:

(i) The need to make assumptions as to the composition of future ecosystem services flows. Most likely it is only relevant in an accounting context to determine this composition based on a continuation of business as usual rather than developing a range of alternative scenarios for the use of the ecosystem. (The development of alternative scenarios for analytical purposes is possible as an extension of the SEEA Experimental Ecosystem Accounting.)

(ii) As part of developing expected estimates it is necessary to formulate an asset life – i.e. 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 view on the extent to which the delivery of the current set of ecosystem services is sustainable. (It is noted that points (i) and (ii) are necessarily related challenges).

(iii) As with aggregation within ecosystems, understanding dependencies between ecosystem services and assets and these dependencies in future periods remains a challenge. Ideally not only would relationships be known in the present period but also how these relationships might change in the future taking into account the likely non-linearities involved. (It is noted that relevant knowledge should also be considered in point (i) and (ii).)

(iv) Derivation of NPV estimates requires the selection of an appropriate discount rate. This is not straightforward and depending on the context may require consideration of various equity and other social 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. This may not be considered appropriate for ecosystems as a whole whose value may be considered not properly reflected at the margin.

5.122 Given all of these considerations, careful thought should be applied before applying standard NPV approaches to the valuation of ecosystem assets. Depending on the analytical and policy requirements, aggregate measures of ecosystem assets may not be required. It is also noted that where integration of 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) is intended, 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 disentangled. This may be particularly relevant in assessing the value of land as distinct from any associated ecosystem asset.

5.123 One motivation for undertaking these valuations is to determine the change in the value of ecosystem assets and hence to 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 6. It is noted here that measurement of the change in the value of ecosystem assets still requires consideration of all of the factors listed above and cannot be simply related to movement in the prices and quantities of ecosystem services in a given accounting period. Under this approach to ecosystem degradation it is the change in the full time series of expected ecosystem services flows that is important.

5.6.3 Benefit transfer

5.124 The discussion of valuation for ecosystem accounting is focused on the development of estimates in monetary terms for large regions or countries that may be used for the development, implementation and/or monitoring of public policy. Much work on valuation has focused on the valuation of ecosystems and ecosystem services in smaller, more targeted settings for specific ecosystems or in relation to particular events, for example the valuation of damages caused by oil spills. Consequently, much data on the value of ecosystem services is 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 taken when value estimates for ecosystem services or ecosystem assets are extrapolated to other areas.

5.125 There are three main types of approaches to benefit transfer: value transfers, benefit function transfers and 'meta-analysis' function transfers. A value transfer takes 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. A more comprehensive way to carry out benefit transfers is to use meta-analysis, which takes all existing studies and then estimates a relationship that gives 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. This is then transferred to the new application in a procedure referred to as meta-regression-value-transfer, which gives a range of values to the new application depending on the characteristics embedded in the meta-regression.

5.126 This approach is well suited to developing estimates for additional sites but may need to be supported with other techniques in order to provide estimates at larger scales, including at the national level.

5.127 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 unlikely to be appropriate and meta-analysis function transfers are likely to be required.

5.128 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 recreational use, there are not as many studies on the value of wetlands. Different valuation studies are also often based on different assumptions and using different methodological constructs leading 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 done poorly. Therefore, there must be focus on increasing the number of observations and different valuation studies to improve the overall quality of outcomes, in addition to efforts aimed at improving benefit transfer methods.

5.6.4 Uncertainty in valuation

5.129 There are significant sources of uncertainty in ecosystem accounting. These can be grouped in four main categories: (i) uncertainty related to physical measurement of ecosystem services and ecosystem capital; (ii) uncertainty in the valuation of ecosystem services and assets; (iii) uncertainty related to the dynamics of ecosystems and changes in flows of ecosystem services; and (iv) uncertainty regarding future prices and values of ecosystem services.

(i) *Uncertainty related to physical measurement of ecosystem services and ecosystem assets* – It is clear that, given data scarcity 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 sub-national) scale, and services flows need to be estimated on the basis of point based observations in combination with spatial data layers and non-spatial statistics. At the same time, it is noted that information related to flows of provisioning services are generally, readily available.

(ii) *Uncertainty in the valuation of ecosystem services and ecosystem assets* – A second source of uncertainty relates to the monetary value of ecosystem services. For provisioning services, a key aspect is that attributing a resource rent to ecosystems involves a number of assumptions regarding rent generated by other factors of production. For non-market ecosystem services, it is often difficult to establish both the demand for these services and to reveal the supply of these services by ecosystems, in particular at an aggregated scale.

(iii) *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 recognised that ecosystem changes are often sudden, involving thresholds at which rapid and sometimes irreversible changes to a new ecosystem state occur. Predicting the threshold level at which such changes occur is complex and prone to substantial uncertainty.

(iv) *Uncertainty regarding future prices and values of ecosystem services* – Pricing benefits and costs that may accrue in the far-distant future is complex because it is extremely difficult to predict our circumstances in the future. The ecosystem implications of humanity's continuing modification of the climate and landscape are uncertain, and those implications are likely both to affect and to depend on how the future evolves. Uncertainties concerning values are even greater inasmuch as the methods of nonmarket valuation compound errors in estimation.

5.130 The best strategy to deal with the sources of uncertainty will vary by country as a function of data availability and relevant services selected for ecosystem accounting. Given the limited experience to date in analysing ecosystem services in both physical and monetary terms at the national level, the approaches to limiting these uncertainties and maximise the robustness of ecosystem accounting will need to be further developed once more practical experience with ecosystem accounting has been gathered and evaluated. The experiences gathered with national level assessment of ecosystem services supply are also highly relevant in this context[68] and thus it is important that all projects provide clear information on the scope of the ecosystem services that have been valued and the relevant assumptions and uncertainties.

[68] See for example the UK National Ecosystem Assessment (2010)

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 measured in monetary terms. One way of bringing this information together is to create combined presentations that combine measures in physical terms for ecosystem services and ecosystem assets with standard economic measures such as value added, income, and employment. Following the descriptions in Chapter 6 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 valuation in monetary terms is not possible for some accounting entries but relevant physical information may still be of use. Section 6.2 describes relevant measurement issues.

6.2 A second way of considering ecosystem accounting in monetary terms is to bring together valuations of stocks and flows of ecosystem assets into an ecosystem asset account following the standard asset account structure outlined in the SEEA Central Framework. 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 in monetary terms 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 the standard national accounts and aggregates. There are a number of motivations for considering this integration generally around the notion that in a number of situations it is beneficial to provide information on economic and other human activity that take place outside the market and/or is not recorded in the standard economic measures of production, consumption, income and wealth. Providing this information in a manner that relates directly to the standard economic measures significant aids analysis and interpretation. It is therefore usual for work in this area to start from the concepts and structures of the SNA and seek to find ways in which alternative presentations and aggregates may be formulated.

6.4 This chapter introduces possible areas of integration between ecosystem accounting and standard presentations of economic accounts but deliberately refrains from providing specific recommendations. This is done for a number of reasons:

(i) First, 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.

(ii) Second, there are concerns within the official statistics community about whether the types of adjustments and extensions to the SNA that are commonly described fall within the purview of official statistics.

(iii) Third, there has been no definitive conclusion to the technical discussion on integration of ecosystem accounting with the SNA and alternative presentations may be justified depending on the particular environmental situation or question of policy interest.

(iv) Fourth, there remains a range of significant measurement challenges.

6.5 Notwithstanding these concerns, SEEA Experimental Ecosystem Accounting would be incomplete without placing in context considerable effort that has been devoted to conceptualising adjustments and extensions to the SNA. It is therefore appropriate that the key measurement issues in accounting for ecosystems in monetary terms are introduced in this chapter. This is done in Section 6.4.

6.6 The discussion of combining ecosystem accounting with standard national accounts is increasingly relevant as countries, both nationally and multi-nationally, are recognising the scarcity of some ecosystem services and are developing policy instruments to manage this scarcity. Where new property rights are established and new transactions arise, there is an overlap between the aim of adjusting for environmental concerns and the inclusion of these transactions in the existing framework of the SNA. Thus, for example, the treatment of payments for tradable emission permits is an important issue for the SNA as there are actual transactions, assets and liabilities that must be recorded. To the extent that ecosystem services are "internalised" in the SNA, there is need to understanding the changing measurement boundary.

6.2 Combined presentations for ecosystem accounting

6.2.1 Introduction

6.7 Combined presentations are a way of assessing changes in stocks and flows of ecosystems in the context of standard measures of economic activity without undertaking the step of valuation of ecosystem services and ecosystem assets in monetary terms. An example of a combined presentation is one comparing expenditures on environmental protection for a specific ecosystem asset with changes in ecosystem condition in physical terms for the same ecosystem 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 related to the environment. The SEEA Central Framework Chapter 4 covers the recording of the relevant transactions by: (i) describing the compilation of Environmental Protection Expenditure Accounts (EPEA) and statistics on the Environmental Goods and Services Sector (EGSS); (ii) defining environmental taxes and environmental subsidies and similar transfers; and (iii) 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 for these transactions as outlined in the SEEA Central Framework apply equivalently in SEEA Experimental Ecosystem Accounting. This reflects that the treatments in the SEEA Central Framework are elaborations of the treatments of the transactions from a standard SNA perspective and 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, this section outlines some particular aspects of the general treatment of transactions related to the environment that are likely to be most relevant when assessing ecosystems. The particular aspects outlined are: information on environmental activity; linking ecosystems and ecosystem services to economic activity; and the treatment of payments for ecosystem services.

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 a primary purpose of either the prevention, reduction and elimination of pollution and other forms of degradation; or preserving and maintaining the stock of natural resources. Generally, it has been expenditure on these types of activities that has been the focus of accounting, however, increasingly there is interest in measuring the production of environmental goods and services, i.e. those products produced for the purpose of environmental protection or resource management and relevant adapted goods. (For details see the SEEA Central Framework, Chapter 4).

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 is organised on the same spatial scales this would facilitate the monitoring of the effect of expenditures on changes in ecosystems. For example, information may be organised by type of LCEU, combining information on expenditure to restore coastal wetlands with information on associated changes in ecosystem condition.[69]

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 focused on the maintenance and restoration of ecosystems. The compilation of targeted statistics on the production of ecosystem related environmental goods and services, with 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 ecosystems 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

[69] It may be difficult to allocate survey data collected at national level to specific ecosystem assets. Thus, it may be necessary to consider alternative approaches to collecting site specific expenditures, for example through administrative sources.

ecosystems and standard measures of economic activity, such as GDP. For example, it may be of interest to understand the contribution of ecosystem services to agricultural production.

6.15 A useful approach is to align the spatial coverage of ecosystem data and measures of economic activity, perhaps using information on land use or land ownership, such 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 noted that the most appropriate spatial boundaries will vary for different ecosystem services and this may need to be taken into account in interpreting any detailed spatial information.) Additional benefit would be gained by also integrating estimates of population at aligned geographic levels. Increasingly, socio-economic data are being organised at finer levels of detail using GIS and related techniques. Nonetheless, a balance will need to be found between the potential for disaggregating economic data to finer spatial level and the meaningfulness of aggregating ecosystem data to higher 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 which a clear link can be established between an ecosystem and the location of the production – for example, agriculture, forestry, fishing, and tourism. 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 take place in relation to the economic activity. For example, payments of certain environmental taxes, payments of rent on natural resources, payments 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 A specific case of a link between ecosystems and economic transactions is the case of payments for ecosystem services (PES). PES are incentives offered to landowners (often farmers) in exchange for managing their land to provide some type of ecosystem services.The payments reflect "a transparent system for the additional provision of environmental services through conditional payments to voluntary providers"[70]. In the context of PES the payments relate to ecosystem services that contribute to non-SNA benefits. It is 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 their general title, no payments are made to the ecosystem

[70] Tacconi, L. (2012). Redefining payments for environmental services. *Ecological Economics*, 73 (1): 29-36.

generating the relevant ecosystem services. Rather, payment is made to an economic unit who, in return, undertakes various remedial actions or changes patterns of use of the ecosystem (including potentially not undertaking economic activity), with the objective of maintaining or increasing the supply of ecosystem services.

6.20 Given the conceptualisation for ecosystem services that has been developed in SEEA Experimental Ecosystem Accounting it is reasonable to conclude that any payments reflect the "marketisation" 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 noted that the economic unit may also be required to incur current and capital expenditure and these are likely to be already recorded following SNA accounting practices.

6.21 The situation is analogous to the treatment of the provision and consumption of services within the home. Following SNA, child care by parents at home is considered outside the production boundary, but where child care services are provided by economic units in return for money (or similar) the activity in considered inside the production boundary.

6.22 In a combined presentation, a spatial organisation of information 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 previous sub-section) and 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 5 of the SEEA Central Framework, this section outlines 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 as applied in the case of produced assets. In short, this application of the model requires that the values of ecosystem service flows are interpreted as analogous to income flows. Since the set of ecosystem service flows described in SEEA Experimental Ecosystem Accounting contribute to both SNA and non-SNA benefits, it implies that the production boundary, and the associated boundaries of consumption and income, are broader in SEEA Experimental Ecosystem Accounting compared to the SEEA Central Framework and the SNA. The extension of the income boundary ensures that there is alignment between the characterisation 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 undertaking such an accounting exercise. A particular concern is related to comparison and aggregation across various types of assets (e.g. produced assets, environmental assets, 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. 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 Following the introduction of a possible structure of an ecosystem asset account in monetary terms, most of this section is devoted to discussion of the valuation of ecosystem degradation. This has been a significant focus of work over many years and the key elements of the discussion are summarised. The discussion builds on the discussion of ecosystem degradation in physical terms in Chapter 4 and readers are encouraged to review that material before considering valuation issues. Overall, there are significant conceptual and measurement challenges involved in developing ecosystem asset accounts and this section is intended to introduce the possibility rather than recommend 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 concept, the value of an ecosystem asset may be considered to be equal to the discounted values of expected ecosystem service flows. These discounted 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 the development of asset accounts for particular LCEU and then aggregate to the EAU level. In large part however, the determination of the level of estimation will depend on the approaches that are taken to the estimation of ecosystem service flows in physical and monetary terms. The information might also be presented in combination with information in physical terms.

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, particularly those related to reductions due to extraction and harvest[71], reductions due to ongoing human activity and 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 as the extraction of resources. As explained in Chapter 4 there are a range of perspectives that may be taken with regard to ecosystem degradation, especially in relation to the accounting treatment for ecosystem conversions. Further discussion on the measurement of ecosystem degradation in monetary terms is presented in the following sub-section.

[71] It is 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 SEEA Central Framework Section 5.4.

Table 6.1 Stylised Ecosystem Asset Account Entries

	EAU or LCEU
Opening stock	
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	

6.30 The value of ecosystem degradation is only part of accounting for 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, e.g. floods, fires, etc
- 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 replantings of native species in deforested areas are undertaken. Major restorations of degraded ecosystems should be considered distinctly from relatively continuous patterns of re-planting that may take place 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 Accounting 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 accounts valued on the basis of the costs of undertaking the improvements. 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 in monetary terms an aggregate value for expected ecosystem services flows is derived, the most straightforward approach to measuring ecosystem degradation is as the change in value of expected ecosystem service flows over an accounting period. However, in the case of ecosystem conversions[72] there is a change in the basket of ecosystem services and hence the change in value of expected flows also incorporates 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 perspective taken is one in which the ecosystem asset is considered as a whole. In this case, ecosystem degradation is conceptualised in an aggregate sense rather than being considered in terms of separable ecosystem service flows. The most common approach to the valuation of ecosystem degradation in this situation is to estimate the restoration cost – i.e. the estimated expenditure required to return the ecosystem asset to the condition that existed at the beginning of the accounting period.

6.35 There is a range of concerns about the use of a restoration cost approach. These include 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 the approach is a direct measure of a possible value of ecosystem degradation that can be estimated in a manner commonly used in the estimation of the value of public goods in the national accounts. Further, even if not used to value degradation, estimates of restoration cost may be of interest in their own right.

Damage-based 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" – so-called damage-based estimates; or whether it should be approached from the perspective of "how much would it cost to avoid ecosystem degradation" – cost-based estimates. There was no expectation that estimates obtained from the different perspectives should align although the extent of ecosystem degradation in physical terms was assumed to be the same in each case. The differences and the relevant accounting implications are described in detail in Chapters 9 and 10 of the SEEA-2003.

[72] 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.

6.38 Consideration of ecosystem degradation in the context of ecosystem services does clarify the scope of damage-based and cost-based perspectives to a significant degree. Thus damage based assessments should focus on the value of the reduction in 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 having both may be useful for 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 have already been accounted for in the standard SNA asset accounts as either consumption of fixed capital or other changes in volume. In practice, ensuring that extent of damages is appropriately attributed to assets such that they are only recorded once is likely to be a complex accounting exercise. It is necessary to consider (i) whether the changes in the ecosystem are normal and long lasting, (ii) the linkages to related effects such as productivity and human health which may or may not be captured in the SNA, and (iii) the relationship between the value of an ecosystem service and the value of the benefits to which an ecosystem service 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 approach taken to the measurement of ecosystem degradation, there may be interest in understanding the relationship between ecosystem degradation and specific economic units – enterprises, households, and governments. In this regard a choice must be made as to whether the measures of ecosystem degradation in monetary terms are allocated to economic units in terms of the ecosystem degradation they cause through their economic and human activity (activity based allocation), or 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. These allocations may be difficult because there will not be a neat spatial relationship between 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 between the time at which ecosystem degradation occurred and the time at which the impacts of the degradation were felt by the various economic units.

6.4 Integration of ecosystem accounts and economic accounts in monetary terms

6.4.1 Introduction

6.42 This section introduces three ways in which ecosystem accounting information may be used to augment the economic accounts of the SNA:

(i) 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. This approach also brings into consideration approaches described in the literature as wealth accounting.

(ii) The compilation of a sequence of economic accounts taking into account ecosystem services and other ecosystem flows, especially ecosystem degradation;

(iii) The derivation of aggregate measures of economic activity, such as income and saving, that are adjusted for ecosystem degradation.

6.43 The extent to which estimates of ecosystem services, ecosystem degradation and related measures can be used to augment standard economic accounts depends on the underlying approach taken to the conceptualisation of ecosystem assets and ecosystem services. Where the value of ecosystem assets is conceptualised as being directly related to expected ecosystem service flows, there is the potential to develop 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 recognised that the augmentation of standard economic accounts does not imply that there is a simple extension or addition of ecosystem accounting information. Rather, there are many entries in the standard accounts that must be re-considered in the light of efforts to highlight ecosystem accounting flows and care must be taken to ensure that, where relevant, an appropriate partitioning of accounting entries takes place to avoid double counting.

6.45 This section introduces what may be possible but deliberately refrains from providing recommendations. This is done for the reasons outlined in the introduction: differing views on the meaningfulness of augmented accounts, concerns about the link to official statistics, the size of the measurement challenges, and the lack of conclusion to the technical debate among accountants as to how any augmentation should take place.

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 based on outputs from a modelling process. Generally, this distinction is a matter of degree since all national statistics require assumptions of various kinds to aggregate detailed observations. At issue is the robustness of the assumptions and the quality of the modelling. This will vary from case to case.

6.47 While there are a number of concerns at a technical and interpretative level, it is important that work that has been undertaken to augment the standard national accounts is placed in the correct context such that those working in that area or those seeking to understand the work have a basis for their deliberations.

6.48 Work on adjusting or extending SNA income accounts and balance sheets must be considered in the context of the objectives, concepts and measurement challenges outlined in Chapters 1-5 of this document. Three aspects in particular must be highlighted. First, adjustment requires assessment of ecosystems in physical terms. Second, adjustment or extension requires valuation techniques to be used to derive estimates in monetary terms. Third, adjustment requires aggregated measures of ecosystem services and ecosystem assets.

6.4.2 Balance sheets and wealth accounting

6.49 Measures of wellbeing and progress are often considered in the context of sustaining a broad stock of assets, capital or wealth. In broad terms, wellbeing is said to be sustainable if the stock of assets is non-declining over time. Various models can be found in the literature which 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 is to use the general balance sheet framework of the SNA and extend the 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 5 is consistent with this approach. The second approach consists of 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.[73] The third approach is to estimate shadow prices for all of the asset types, including ecosystem assets. As explained in Chapter 5, 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.[74] Both the second and third approaches require the use of economic models but may be differentiated by each having different assumptions concerning sustainability. As well, in practice, the asset boundaries of these different approaches may not be fully aligned although all of these approaches do incorporate ecosystem assets.

6.51 A general concern regarding the extensions made to the balance sheets is that by presenting the values of different assets side by side it may easily be interpreted as meaning that all of the assets are substitutable. Indeed, in some cases the underlying assumption that the sustainability of wellbeing only requires maintenance of 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, thus leading to the notion of critical natural capital.

6.52 In theory, estimates of shadow prices should take into account the extent to which there are 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.

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[73] See for example, World Bank (2010) *The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium*

[74] See for example, UNEP (2012) *Inclusive Wealth Report*

6.53 In practice, there are significant measurement challenges in extending the asset boundary to encompass a broad range of assets not included in the SNA and there are ongoing discussions about the appropriate conceptual basis for making these extensions.

6.54 For SEEA Experimental Ecosystem Accounting the only extensions to the SNA balance sheet that are considered 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 neat and the values of many ecosystem assets are already partially reflected in the value of economic assets recorded in SNA based balance sheets. The remainder of this section describes the boundary issues that should be taken into account.

6.55 It is 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. Hence there is a potential double counting of asset values if the conceptual overlaps described here are not addressed.

6.56 Treatment of biological resources. Following the SEEA all natural and cultivated biological resources are considered within scope of ecosystem assets. Thus, in aggregating measures of economic and ecosystem assets, care should be taken to avoid double counting. Care may also be required in considering the scope of cultivated biological resource that are intensively managed (e.g. intensive livestock and horticulture systems) to ensure that the relevant assets are recorded once only.

6.57 Treatment of mineral and energy resources. These natural resources are defined in the SEEA Central Framework and are not considered a part of ecosystem assets as the benefits they provide are not the result of ecosystem processes. These resources will generally need to be added to ecosystem assets to obtain a broader notion of environmental assets but they may already be included as part of economic assets consistent with the scope outlined in the SNA.

6.58 Special consideration may be required of peat resources which may be used as a form of fossil fuel (and are a part of mineral and energy resources), but which also are a widely distributed type of soil. In particular, peat soils are a very significant store of carbon in many different ecosystems. Care should be taken to avoid double counting of peat soils.

6.59 Treatment of energy from renewable sources. Renewable sources of energy (such as wind and solar sources) cannot be exhausted in a manner akin to fossil energy resources and neither are they regenerated as is the case with biological resources. Thus, in an accounting sense, there is no physical stock of renewable sources of energy that can be used up or sold.

6.60 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 and no additional valuation in relation to these flows is required.

6.61 Treatment of water resources (excluding marine). Depending on the nature of the stock of water in a country, some deep, sub-soil water may be considered not part of ecosystem operation and hence would lie outside the boundary of ecosystem assets. In that case additional valuation may be required.

6.62 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 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 thus the volume of water is not a measurement target per se.

6.63 Special consideration may be required in relation 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. From the perspective of SEEA Experimental Ecosystem Accounting, no specific guidance is provided on the precise geographic scope that should be applied in the context of marine areas. Thus care should be taken to align the scope of aquatic resources captured in measures of both economic assets and ecosystem assets. In this regard the treatment of migrating and straddling fish stocks may be of particular interest.

6.64 Treatment of land. In some cases, the value of land as recorded in the SNA will provide a useful comparison point to the value of ecosystem assets for particular ecosystems. Thus for example, it would be envisaged that the value of agricultural land following the SNA would provide a value including many ecosystem services, at least from the perspective of those ecosystem services within the scope of the SNA production boundary. However, there are a number of specific boundary issues that should be considered:

(i) 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.

(ii) SNA land values will incorporate, perhaps to a significant extent, the effect of the location of the land. This location value does not 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 hence will impact on the overall valuation of those services. Consequently, the links between land values and values of ecosystem assets may not be able to be neatly distinguished.

(iii) Some areas of land, perhaps of high ecological significance, may not be able to be traded (for example national parks) and hence may not be included in the scope of the SNA asset boundary since no observable market exists or 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 provided from these areas of land.

(iv) 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 noted that urban populations use significant quantities of ecosystem services, both directly and indirectly. While urban ecosystems may be of interest they may not often be considered a focus of ecosystem accounting. Hence, care should be taken to ensure that the geographic boundaries being applied in the measurement of ecosystem assets ensure appropriate coverage of economic and ecosystem assets in urban areas.

6.65 Since the measurement of ecosystem assets is undertaken starting from a spatial scale, ideally, adjustments to align the measurement boundaries between ecosystem assets and economic assets should also be undertaken spatially. This is particularly the case when considering 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 within a given area function. 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 when attempting to allocate estimates of national wealth to the institutional sector level.

6.4.3 Sequence of accounts

6.66 A sequence of accounts presents the relationships between all stocks and flows recorded in an accounting system and embodies the relationships in the accounting framework. The starting point for the SEEA sequence of accounts is the standard SNA 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, i.e. corporations, general government, households and non-profit institutions serving households (NPISH).

6.67 Compared to the SNA, the additional feature of the sequence of accounts described in the SEEA Central Framework is the incorporation of entries for depletion in the various accounts. This addition is described in detail in Chapter 6 of the SEEA Central Framework. Overall, the sequence of accounts shows very little variation from the standard SNA sequence of accounts.

6.68 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 4. Over the past 20 years a range of alternative accounting proposals have been made.

6.69 The most significant structural choice for a sequence of accounts for ecosystem accounting is whether ecosystems are considered to constitute a separate quasi-institutional sector, alongside corporations, general government, households, and NPISH, or whether ecosystem assets are a part of the broader stock of assets used by the various institutional sectors and hence no additional, quasi-sector is needed. Annex A6.1 describes in more detail the possible models regarding a sequence of accounts for ecosystem accounting.

6.4.4 Adjusted income aggregates

6.70 It has long been recognised 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, extreme weather), externalities of production, and various non-economic impacts on welfare, such as life satisfaction. In the context of environmental-economic accounting there is no ambition to account for all of these factors and hence any adjusted income aggregates that may be derived should not be interpreted in the very broad sense that may be envisaged.

6.71 Notwithstanding the potential limitation of a focus only on environmental factors that affect welfare, 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 SEEA Central Framework Chapter 6).

6.72 Beyond the environmental costs of depletion, there have been ambitions to derive measures that adjust for the costs of ecosystem degradation. Often these measures are referred to as Green GDP but this single term has also been applied to many concepts and approaches to adjusted income measures and increasingly is used in a different context to refer to that part of the conventionally measured economy that is considered environmentally related. Thus, measures labelled Green GDP do not refer to a common, single concept.

6.73 The measurement of ecosystem degradation in monetary terms points to one way in which an adjustment to income aggregates within the SNA may be adjusted for the costs of degradation. To retain 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. From this broader income measure, a measure of ecosystem degradation may be deducted to derive degradation adjusted aggregates.

6.74 While this basic approach is conceptually possible, the potential for alternative attributions of ecosystem degradation to different economic units and the significant underlying measurement challenges and assumptions, means that no specific adjusted income measure is proposed or recommended in SEEA Experimental Ecosystem Accounting.

6.75 Beyond the challenges already noted in this chapter, and as with all of the measures and aggregates in monetary terms, adjusted income aggregates suffer from the difficulty that the values of the environmental variables cannot generally be made in a full, open market context. Consequently, the valuations are, at best, estimates of prices at partial equilibriums. Extended modelling is possible in which attempts are made to estimate what GDP (and other income measures) would be if alternative environmental constraints were in existence. So-called greened economy modelling thus derives a measure of income for an alternative view of the economy rather than deriving an alternative measure of income for the existing economy. There are no specific conceptual accounting issues in following this approach but it is an approach founded in modelling based on alternative scenarios and is thus outside the scope of the SEEA.

Annex A6.1 Possible models for a sequence of accounts for ecosystem accounting

A.6.1 Following on from the brief introduction to the sequence of accounts in Section 6.4, this annex presents a summary of current thinking on possible models that may be used to incorporate entries related to ecosystem services and changes in ecosystem assets into the standard SNA sequence of accounts.

A.6.2 Table A6.1 presents simplified versions of Models A and B. The example is that a farm is a single ecosystem that provides a mix of ecosystem services (total 110) of which 80 are used by the farmer and 30 are the final consumption of households.[75] 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 noted that in the generation of ecosystem services there is no recording of "inputs" from within the ecosystem. This recording is not required for the purposes of developing a sequence of accounts focused on economic units.

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
Int. consumption – SNA	0		0	0	0		0
Int. 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 adj. Net Operating Surplus	**60**		**95**	**155**	**155**		**155**
Allocation and use of income accounts							
Degradation adj. 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
Final consumption – non-SNA		30		30		30	30
Degradation adjusted net saving	**140**	**-150**	**-15**	**-25**	**125**	**-150**	**-25**

[75] The allocation is based on the assumed composition of the ecosystem services – thus the 80 may be considered inputs to agricultural production and the 30 may be considered regulating services, such as air filtration, used by households.

A.6.3 In both models, the rise in GDP only occurs in relation 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).

A.6.4 Measures of GDP may be adjusted for both consumption of fixed capital (CFC) and ecosystem degradation thus providing Degradation adjusted Net Domestic Product.

A.6.5 Under Model A, flows of ecosystem services are recorded in gross terms flowing from ecosystems to relevant units as either intermediate or final consumption. 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.

A.6.6 Under Model B, flows of ecosystem services are recorded in net terms in that "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 to record all flows of ecosystem services in gross terms. As in Model A, GDP rises to the extent of ecosystem services consumed as final consumption.

A.6.7 In standard capital accounting practice, consumption of fixed capital, the costs associated with the use of produced assets, are deducted from the income of the user of the asset. This deduction is obvious 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 much more complex. Consequently, as discussed above alternative approaches to the allocation of ecosystem degradation to economic units must be considered.

A.6.8 In Model A, the full amount of ecosystem degradation is attributed to the new ecosystem quasi-sector. In effect this follows the 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 the capital 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 the farmer.

A.6.9 However, neither of these assumptions provides a complete sense of 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 consideration would turn to the users of the ecosystem services and hence some ecosystem degradation would be attributed to households reflecting their direct and indirect consumption of ecosystem services.

A.6.10 It is important to recognise that in both models flows of ecosystem services are recorded quite distinctly from flows of ecosystem degradation. Allowing for this difference enables a more complete and consistent recording of all ecosystem services, not only those of a particular type, i.e. provisioning, regulating or cultural.

A.6.11 Both models contain an entry named "ecosystem transfers", which is not a standard entry in the SNA. This entry accommodates the additional consumption of ecosystem services by each sector and sums to zero across the economy. The level of the transfers is higher in Model A than in Model B, reflecting that in Model A all ecosystem services are purchased from the ecosystem quasi-sector. The inclusion of this entry means 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 for the recording of ecosystem degradation.

A.6.12 Model A appears straightforward to apply since the ecosystem is presented separately as an adjunct to standard institutional units. Unfortunately, the real depth of integration between ecosystems and economic activity means that isolating ecosystems may be difficult in practice. A particular concern is 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.

A.6.13 Model B reflects a more integrated view of the relationship between ecosystems and economic units. The key difference is reflected by adjustments for ecosystem degradation being made to the income of the producer rather than 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 weak. It would be possible to partition the ecosystem asset across more than one institutional sector but this may not be straightforward. Estimates of ecosystem degradation also need to be partitioned if more than one institutional unit is considered to be involved.

A.6.14 An alternative model that is somewhat of a compromise between Models A and B, is to incorporate an ecosystem quasi-sector where this sector only has outputs that are non-SNA ecosystem services. Such a recording requires a partitioning of ecosystem assets, ecosystem services and ecosystem degradation. This 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. Using relationships between ecosystem service flows and economic units attribution of ecosystem degradation could then be made.

A.6.15 Overall, there is no straightforward choice to the structure of a sequence of ecosystem accounts. Neither Models A or B (or possible variants) present information on all of the relevant flows in as neat a fashion as may be desirable without 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 together (thus clearly pertaining to a specific ecosystem) rather than partitioning this expenditure across multiple ecosystem managers through a series of capital transfers.

Annex I: Research agenda for SEEA Experimental Ecosystem Accounting

Introduction

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, work is required to research 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 in the ongoing development of concepts, methods and classifications on ecosystem accounting. Considering 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.

The research agenda presented in this annex provides a general overview of the main issues to be addressed. The issues have been organized according to broad research areas. These areas reflect the general nature of the focus of the intended work but all issues are closely interconnected and need to be addressed in a coordinated fashion, taking into account initiatives underway in countries and by international agencies.

Areas of research

Three areas of research are proposed – each of these are explained below.

a. Physical ecosystem accounting

b. Monetary ecosystem accounting

c. Communication and dissemination.

Physical ecosystem accounting

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 into 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.

This area of research encompasses work on:

- Delineating spatial units following the broad conceptual model outlined in SEEA Experimental Ecosystem Accounting. This should initially focus 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 (LCEU).

- 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. This multi-dimensional geo-referencing may be considered in the delineation of 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, etc) including understanding measurement of the supply, demand and distribution of ecosystem services and the associated benefits. This work should consider the appropriateness of the proposed classification of ecosystem services (CICES) and the general measurement boundaries discussed regarding ecosystem services in Chapter 3.
- Identifying the main ecosystem characteristics for the measurement of ecosystem condition and relevant indicators of condition for each type of ecosystem (e.g. forests, wetlands, etc). This work should consider the links to spatial units delineation.
- 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, to derive measures across and within ecosystems. In conjunction, methods of downscaling and upscaling information should be investigated.
- Examining the treatment of the so called ecosystem disservices in the ecosystem accounting such as pests and diseases.
- Considering to the assessment of data quality and the accreditation of data sources, particularly scientific and modeled data.

Monetary ecosystem accounting

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 these valuations. Valuation of water has been included in the research agenda of the SEEA Central Framework and would benefit from being discussed also in the context of ecosystem accounting.

This area of work encompasses work on:

- Clarifying the alternative ecosystem service pricing techniques and their relevance to determining (i) prices for ecosystem services connected to market goods and services; and (ii) 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 for implementation (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, ecosystem degradation as well as possible derivation of degradation-adjusted macro-economic aggregates.
- Developing the sequence of accounts by institutional sector that incorporate flows relating to ecosystem services and ecosystem assets. This work should distinguish between flows already within scope of the standard economic accounts and extensions to standard measurement boundaries. Also, the work should consider options for the attribution of ecosystem degradation to institutional sector 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 drawn to alternative measures of wealth. Links should also be considered to the recording of entries in the capital account and connections between flows related to ecosystem enhancement and land improvement.

Communication and dissemination

This area of work focuses on communicating the results of ecosystem accounting. This work should encompass:

- Developing combined presentations that show ecosystem accounting information 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 including, but not limited to the analysis of trade-offs – for example between alternative land uses.

Glossary

Introduction

This 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 to the choice of terms and also notes cases where other terms are often used to describe the same or similar concepts.

The content and style is intended to provide additional understanding of the terms and concepts used. The content is also intended to support exchanges between researchers since it is quite common for the same term to be used in relation to different concepts and also, for different terms used to convey the same concept.

The annotated glossary may also be read in conjunction with the structured list of references which provides an overview of the literature that has formed the foundation for the synthesis described 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 references below refer to SEEA Experimental Ecosystem Accounting.

Definitions and descriptions

Abiotic services:

Abiotic services refer to flows from the environment to economic and other human activity that do not arise as a result of bio-physical processes and other interactions within and between ecosystems.

The main examples are flows of mineral and energy resources from underground deposits, energy from the sun for the growing of crops and as a renewable source of energy, the movement of wind and tides which can be captured to provide sources of energy, and the provision of space in areas of land and water to undertake economic and other human activity. (3.19-3.21)

See also Ecosystem services

Basic Spatial Unit (BSU):

A basic spatial unit (BSU) is a small area. Ideally, BSU are formed by delineating tessellations (small areas e.g., 1 km2), typically by overlaying a grid on a map of the relevant territory; but they may also be land parcels delineated by a cadastre or using remote sensing pixels. (2.52)

BSU are the smallest unit in the model used to define areas for the purposes of ecosystem accounting. They can be aggregated to form Land Cover / Ecosystem functional Units (LCEU) and Ecosystem Accounting Units (EAU).

See also Ecosystem Accounting Units, Land Cover/Ecosystem functional Units

Beneficiaries:

Beneficiaries refer to individual and economic units (enterprises, households, governments and those units in the rest of the world) who receive the benefits to which ecosystem services contribute. (see 2.76, 2.98, 3.8, 3.32)

See also Benefits, Ecosystem services, Economic units

Benefits:

Benefits reflect the 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).

In many studies, benefits and ecosystem services are defined synonymously but this is not the approach taken in SEEA Experimental Ecosystem Accounting. In some studies the word "goods" is used to refer to the concept of benefits as defined here. The term "goods" is not used here to avoid confusion with the use of the same term in economic statistics where it relates to the production, consumption and accumulation of tangible items (e.g., as used in the phrase "the production of goods and services").

Two broad types of benefits are described in SEEA Experimental Ecosystem Accounting. SNA benefits comprise the products (goods and services) produced by economic units (e.g. food, clothing, shelter, entertainment, etc) 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 as a result of economic production processes defined by the SNA. Rather they comprise ecosystem services that do not contribute to the production of SNA goods and services.

See also Ecosystem services

Biocarbon:

Biocarbon refers to carbon stored in the biosphere, in living and dead biomass and soils. (4.97)

Biodiversity:

"Biodiversity is 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 ecosystems." (Convention on Biological Diversity (2003), Article 2, 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 from the measurement of changes in ecosystem extent and condition.

See also Ecosystem characteristics

Consumer surplus:

Consumer surplus is the gain obtained by consumers because they are able to purchase a product at a market price that is less than the highest price they would be willing to pay. (5.19)

See also Exchange value, Producer surplus, Welfare economic value

Cultural services:

Cultural services relate to the intellectual and symbolic benefits that people obtain from ecosystems through recreation, knowledge development, relaxation, and spiritual reflection. (3.4(iii))

See also Ecosystem services, Provisioning services, Regulating services.

Degradation (see Ecosystem degradation)

Depletion:

Depletion, in physical terms, 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 defined distinctly from ecosystem degradation in that it refers to the decrease in a specific individual environmental asset rather than the decline in the functioning of an ecosystem asset as a whole. Nonetheless there are likely to be close connections between depletion and ecosystem degradation in specific spatial areas.

Note that depletion only relates to decreases in natural resources (i.e. it does not cover cultivated biological resources), and does not apply to land (noting that there may be depletion of soil resources, for example 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.

Economic units:

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 recognised independently of the people that own or control them. Groupings of institutional units that are similar in their purposes, objectives and behaviours are defined as institutional sectors. Following SNA, five types of institutional sector are recognised: Households, Non-financial corporations, Financial corporations (in the SEEA these two are usually combined as 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.

For more details see 2008 SNA Chapter 4, SEEA Central Framework Chapter 2.

Ecosystems:

"Ecosystems are a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit." (Convention on Biological Diversity (2003), Article 2, 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 Units, Land Cover/Ecosystem functional units.

Ecosystem Accounting Unit (EAU):

Ecosystem Accounting Units (EAU) are large, mutually exclusive, spatial areas delineated on the basis of the purpose of accounting. Generally, they will reflect a landscape perspective. Factors considered in their delineation include administrative boundaries, environmental management areas, socio-ecological systems and large scale natural features (e.g. river basins). (2.64)

A hierarchy of EAU may be established building from a landscape scale to larger sub-national and national boundaries. EAU at the landscape level may be considered to reflect ecosystem assets. EAU are the highest level of the spatial model used to define areas for the purposes of ecosystem accounting.

See also Basic Spatial Units, Land Cover/Ecosystem functional Units, Ecosystem assets

Ecosystem assets:

Ecosystem assets are spatial areas containing a combination of biotic and abiotic components and other characteristics that function together. (2.31, 4.1)

Depending on the analysis being conducted, an ecosystem asset may be defined to contain a specific combination of ecosystem characteristics (e.g., a tropical rain forest represented by an LCEU) or it may contain areas that contain a variety of combinations of ecosystem characteristics (e.g., a river basin containing wetlands, agriculture and settlements represented by an EAU).

Ecosystem assets should be distinguished (a) from the various individual components (e.g. plants, animals, soil, water bodies) that are contained within a spatial area; and (b) from 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 (for example in the SEEA Central Framework many individual components are considered 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" as the word "assets" is more aligned with the terminology employed by the SNA and also conveys better the intention for ecosystem accounting to encompass measurement in both monetary and physical terms. In general however, the terms “ecosystem assets” and “ecosystem capital” may be considered synonymous.

See also Ecosystems, Ecosystem Accounting Unit, Land Cover/Ecosystem functional Unit, Ecosystem 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 but it is linked to the general model of ecosystem assets and ecosystem services that is described. In general terms, the concept of ecosystem capacity refers to the ability of a given ecosystem asset to generate a set of ecosystem services in a sustainable way into the future. While this general concept is very 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 services, Ecosystem condition

Ecosystem or ecological capital:

Ecosystem or ecological capital 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 characteristics:

Ecosystem characteristics relate 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 Section 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 the use of the generic term “characteristics” may seem to be more usefully replaced with terms such as “components” or “aspects”. However, in describing the broader concept of an ecosystem, the use of the term characteristics is intended to be able to encompass all of the various perspectives taken to describe an ecosystem.

See also Ecosystems, Ecosystem assets, Ecosystem condition

Ecosystem condition:

Ecosystem condition reflects the overall quality of an ecosystem asset, in terms of its characteristics. (2.34)

Measures of ecosystem condition are generally combined with measures of ecosystem extent to provide an overall measure of the state of an ecosystem asset. Ecosystem condition also underpins the capacity of an ecosystem asset to generate ecosystem services and hence changes in ecosystem condition will impact on expected ecosystem service flows.

See also Ecosystem assets, Ecosystem characteristics, Ecosystem extent, Expected ecosystem service flows.

Ecosystem conversion:

Ecosystem conversions reflect changes in the extent or composition of an ecosystem asset from one ecosystem type to another that are considered significant or irreversible (e.g., due to deforestation to create agricultural land). (4.32)

Ecosystem degradation:

Ecosystem degradation is 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 flows. 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 4.27-4.32)

Ecosystem enhancement:

Ecosystem enhancement is the increase and/or improvement in an ecosystem asset that is due to economic and other human activity. (4.38)

Ecosystem extent:

Ecosystem extent refers to the size of an ecosystem asset, commonly in terms of spatial area. (2.37)

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 ecosystem extent may be measured in terms of the proportion of an area of a specific combination of characteristics to the total area of the ecosystem asset. For example, the extent of wetlands may be 30% of the area of a river basin.

See also Ecosystem asset, Ecosystem condition

Ecosystem goods and services (see Ecosystem services)

Ecosystem services:

Ecosystem services are the contributions of ecosystems to benefits used in economic and other human activity. (2.23)

The definition of ecosystem services in SEEA Experimental Ecosystem Accounting involves distinctions between (i) the ecosystem services, (ii) the benefits to which they contribute, and (iii) the well-being which is ultimately affected. Ecosystem services should also be distinguished from the ecosystem characteristics, functions and processes of ecosystem assets.

Ecosystem services are defined 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 role of ecosystem characteristics that are together reflected in ecosystem processes.

A range of terms is used to refer to the concept of ecosystem services defined here. Most common are the terms "ecosystem goods and services" and "final ecosystem services". These two terms highlight particular aspects of the definition above. The first recognises that ecosystem services includes flows of tangible items (e.g. timber, fish, etc) in addition to intangible services. The second recognises that only those ecosystem services that contribute to a benefit – i.e. they are final outputs of the ecosystem – are within scope.

Ecosystem services as defined in SEEA Experimental Ecosystem Accounting exclude abiotic services and hence do not encompass the complete set of flows from the environment. A complete set of flows from the environment may be reflected in the term "environmental goods and services".

Three main types of ecosystem services are described: provisioning services, regulating services and cultural services. The Common International Classification for Ecosystem Services (CICES) is an interim classification for ecosystem services.

See also Abiotic services, Provisioning services, Regulating services, Cultural services, Intra- & Inter-ecosystem flows.

Environmental assets:

Environmental assets are the naturally occurring living and non-living components of the Earth, together constituting the bio-physical 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. First, from the perspective of individual components, i.e., individual environmental assets, that provide materials and space to all economic activities. Examples include land, soil, water, timber, aquatic, and mineral and energy resources.

Second, environmental assets can be considered from the perspective of ecosystems. However, the scope of environmental assets is not the same as ecosystem assets as it includes mineral and energy resources which are excluded from the scope of ecosystem assets.

Also, the scope of environmental assets is broader than natural resources as it includes produced assets such as cultivated crops and plants (including timber, 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 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 5

Expected ecosystem service flow:

Expected ecosystem service flow is an aggregate measure of future ecosystem service flows from an ecosystem asset for a given basket of ecosystem services. (2.39)

In general terms the measure of expected ecosystem service flows is 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 may or may not be able to be produced on a sustainable basis. Thus the measure is not necessarily reflective of sustainable or optimal scenarios of future ecosystem asset use. At the same time the expectations of future ecosystem service flows must be informed by 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 asset, Ecosystem condition

Exchange value:

Exchange value reflects the actual outlays/revenue for all quantities of a product that are transacted. It is equal to the market price multiplied by the quantity transacted. It assumes 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 price, Consumer surplus

Geocarbon:

Geocarbon is carbon stored in the geosphere and 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)

Final ecosystem services (see Ecosystem services)

Individual environmental assets (see Environmental assets)

Intermediate ecosystem services (see Ecosystem services, Inter- & Intra ecosystem flows)

Inter-ecosystem flows:

Inter-ecosystem flows are flows between ecosystem assets that reflect ongoing ecosystem processes. (2.12) An example is the flows of water between ecosystem assets via rivers.

These flows may relate directly or indirectly to flows of ecosystem services. Most commonly, inter-ecosystem flows relate to the flows considered supporting or intermediate services.

See also Ecosystem services, Intra-ecosystem flows.

Intra-ecosystem flows:

Intra-ecosystem flows are flows within ecosystem assets that reflect ongoing ecosystem processes. (2.12) An example is nutrient cycling.

These flows may relate directly or indirectly to flows of ecosystem services. Most commonly, intra-ecosystem flows relate to the flows considered supporting or intermediate services.

See also Ecosystem services, Inter-ecosystem flows.

Land cover:

Land cover refers to 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):

A Land Cover/Ecosystem functional Unit (LCEU) is defined, in most terrestrial areas, by areas satisfying a pre-determined set of factors relating to the characteristics of an ecosystem. Examples of factors include land cover type, water resources, and soil type. (2.56)

LCEU may be considered to represent ecosystem assets and LCEU may often reflect the common conception of ecosystems (e.g. forests, wetlands, deserts, etc). Generally, LCEU represent 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 have a number of different LCEU types.

See also Basic Spatial Units, Ecosystem Accounting Units, Ecosystem assets

Market prices:

Market prices are the amounts of money that willing buyers pay to acquire goods, services or assets from willing sellers. (2008 SNA 3.119)

For details see SEEA Central Framework Section 2.7 and the 2008 SNA Chapter 6.

See also Exchange values

Natural capital:

The term natural capital is not defined in SEEA Experimental Ecosystem Accounting. Commonly, natural capital is used to refer to all types of environmental assets as defined in the SEEA Central Framework. Used in this way natural capital has a broader scope than ecosystem assets as defined in SEEA Experimental Ecosystem Accounting since it includes mineral and energy resources.

Generally, natural capital incorporates broad notions of the set of services from ecosystems in line with the accounting for ecosystem assets described in SEEA Experimental Ecosystem Accounting. In this regard, although aligned in bio-physical terms, natural capital may be considered a broader measure than the measures of environmental assets that are described in the SEEA Central Framework which are limited to consideration of material/SNA benefits.

It is noted that while natural capital would usually incorporate all ecosystem assets there is ample evidence to indicate that very few, if any, ecosystems are uninfluenced by humans and hence there are few ecosystem assets that might be considered purely "natural".

See Benefits, Ecosystem capital, Ecosystem assets, Environmental assets, Natural resources

Natural resources:

Natural resources include 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., they 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)

Payments for ecosystem services (PES):

Payments for ecosystem services are generally defined as voluntary and conditional transactions over well-defined ecosystem services between at least one supplier and one user. (6.18)

Producer surplus:

Producer surplus is the amount that producers benefit by selling at a market price that is higher than the least that they would be willing to sell for, which is a function of their production costs.

See also Consumer surplus

Provisioning services:

Provisioning services reflect 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(i))

See also Ecosystem services, Regulating services, Cultural services

Recreational services (see Cultural services)

Regulating services:

Regulating services result from the capacity of ecosystems to regulate climate, hydrological and bio-chemical cycles, earth surface processes, and a variety of biological processes. (3.4(ii))

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

SNA benefits (see Benefits)

Species abundance:

Species abundance is a measure of the absolute number of a particular species in an area. (4.122)

Species richness:

Species richness is a measure of the number of different species in an area. (4.122)

Supporting services (see Ecosystem services, Intra- & Inter-ecosystem flows)

Welfare economic value:

Welfare economic values reflect the total (or gross) economic gain associated with the quantities of a product that are transacted. They include both the consumer and producer surplus and are different from exchange values to the extent of consumer surplus.

Welfare economic values may also reflect the net economic gain, which is equivalently derived as either the total economic gain less the costs of production, or as consumer surplus plus producer surplus.

See also Exchange value, Consumer surplus, Producer surplus

References

The listing of references that follows has been structured according to broad topic within the general subject of ecosystem accounting. It is intended that this approach aids those aiming to develop their understanding of ecosystem accounting through recognition of the different streams of research and literature that are relevant to the subject. Broadly the topics that have been used to structure the references align with the chapter structure of the main text of SEEA Experimental Ecosystem Accounting.

The coverage of references is not limited to those that have been of direct use in informing the drafting of SEEA Experimental Ecosystem Accounting. Rather, the intent has been to provide a broad base of resources recognising the various contributions by many researchers in the different topic areas. In particular, it is noted that although ecosystem accounting as described here is a relatively recent development, its description builds on many long-standing pieces of research in a number of different fields. While broad in coverage, the list of references is not intended to be exhaustive and researchers are encouraged to seek complementary materials in the course of developing and testing ecosystem accounting.

The topics covered are:

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

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