System of Environmental-Economic Accounting

Ecosystem Accounting

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

System of Environmental-Economic Accounting—Ecosystem Accounting

White cover (pre-edited) version

Version: 29 September 2021

Suggested citation: United Nations et al. (2021). System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA). White cover publication, pre-edited text subject to official editing. Available at: https://seea.un.org/ecosystem-accounting.

Department of Economic and Social Affairs

The Department of Economic and Social Affairs of the United Nations is a vital interface between global policies in the economic, social and environmental spheres and national action. The Department works in three main interlinked areas: (i) it compiles, generates and analyses a wide range of economic, social and environmental data and information on which United Nations Member States draw to review common problems and to take stock of policy options; (ii) it facilitates the negotiations of Member States in many intergovernmental bodies on joint courses of action to address ongoing or emerging global challenges; and (iii) it advises interested Governments on the ways and means of translating policy frameworks developed in United Nations conferences and summits into programmes at the country level and, through technical assistance, helps build national capacities.

Note

The designations employed and the presentation of the material in the present publication do not imply the expression of any opinion whatsoever on the part of the United Nations concerning the legal status of any country or of its authorities, or the delimitations of its frontiers. The term "country" as used in this publication also refers, as appropriate, to territories or areas. The designations of country groups are intended solely for statistical or analytical convenience and do not necessarily express a judgment about the stage reached by a particular country, territory or area in the development process. Mention of the names of firms and commercial products does not imply endorsement by the United Nations. The symbols of United Nations documents are composed of capital letters and numbers. Mention of such a symbol refers to a United Nations document.

Contents

Tables

Figures

Acknowledgements

Background

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

(a) Identifying and securing agreement on the issues to be considered in the drafting of SEEA Ecosystem Accounting;
(b) Research on those issues and presentation of proposals for addressing them;
(c) Consideration by experts of the issues and proposals and agreement on a provisional draft text;
(d) Consultation with countries and experts on specific issues as well as complete chapters, incorporation of comments elicited through the consultation process, and preparation of a final draft of SEEA Ecosystem Accounting;
(e) Presentation of the draft to the United Nations Statistical Commission at its fifty-second session, held in March 2021.

The SEEA EA revision was officially launched in March 2018 at the 49th session of the United Nations Statistical Commission. It was centred around four research issues identified as priority areas for the revision – spatial areas, ecosystem condition, ecosystem services and valuation, and five working groups were established to deal with these issues. Each group has drafted a set of discussion papers that were assessed by a group of expert reviewers.

The SEEA EA revision was generously co-financed from contributions made by Australia (Australian Bureau of Statistics and Department for Environment and Energy), the United Kingdom of Great Britain and Northern Ireland (Office of National Statistics and Department for Environment, Food and Rural Affairs), and the European Union (Eurostat).

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

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

The Statistical Commission established the Committee at its thirty-sixth session in March 2005 with the mandate, among others, to oversee and manage the revision of the SEEA. The Committee comprises senior representatives of national statistical offices and international agencies. The Bureau of the Committee, whose representatives are elected from among the members, acts under authority delegated by the Committee. The Bureau manages and coordinates the current activities of the Committee in between its regular sessions.

Since 2015, the Committee and its Bureau were chaired by Bert Kroese (Netherlands) and the secretariat was provided by UNSD.

Members of the Committee of Experts, and other contributors, representing national institutions

Amanda Clark and Jonathon Khoo (Australia), Norbu Ugyen (Bhutan), Rebecca Palis (Brazil), Carolyn Cahill and Greg Peterson (Canada), Zheng Xuegong and Shi Faqi (China), Cobaleda Martínez, Diego Andrés and Paola Andrea (Colombia), Kirsten Balling and Ole Pedersen (Denmark), Kaia Oras (Estonia), Johanna Pakarinen and Jukka Muukkonen (Finland), Françoise Nirascou (France), Sven Kaumanns (Germany), Pravin Srivastava, P. Bhanumati and Shailja Sharma (India), Etjih Tasriah (Indonesia), Aldo Femia and Angelica Tudini (Italy), Carol Coy (Jamaica), Asset Nakipbekov (Kazakhstan), Christine Magu, Hirum Mbatia and Mathew Collins Omondi (Kenya), Nazaria Baharudin and Siti Zakiah Muhamad Isa (Malaysia), Eduardo de la Torre and Graciela Marquez (Mexico), Ankhzaya Byamba and Erdenesan Eldevochir (Mongolia), Bert Kroese, Gerard Eding and Sjoerd Schenau (Netherlands), Rachael Milichich and Stephen Oakley (New Zealand), Peder Naes and Trine Braathu (Norway), Vivian Ilarina (Philippines), Andrey Tatarinov (Russian Federation), Aliielua Salani (Samoa), Gerhardt Bouwer and Joe de Beer (South Africa), Nils Brown (Sweden), Aliziki Kaudha Lubega and Samuel Echoku (Uganda), Liz McKeown, Neil Wilson, Nicola Shearman and Rocky Harris (United Kingdom), Dennis Fixler (United States of America).

Representatives of international organizations

Anton Steurer (Eurostat), Caitriona Maguire, Jan-Erik Petersen and Jock Martin (European Environment Agency), Francesco Tubiello (Food and Agriculture Organization of the United Nations), Catherine Van Rompaey, Juan-Pablo Castaneda, Raffaello Cervigni and Sofia Ahlroth (World Bank), Clara van der Pol, Hernan Epstein and Leandry Moreno (World Tourism Organization), Daniel Clarke, Myriam Linster and Peter van de Ven (Organisation for Economic Cooperation and Development), Gabriel Quiros and Jim Tebrake (International Monetary Fund), Gemma Van Halderen and Rikke Munk Hansen (Economic and Social Commission for Asia and the Pacific), Jillian Campbell and Markus Lehmann (Secretariat of the Convention on Biological Diversity), Ludgarde Coppens (United Nations Environment Programme), Massimiliano Riva, Midori Paxton and Tim Scott (United Nations Development Programme), Michael Nagy (Economic Commission for Europe), Oliver Chinganya and Xiaoning Gong (Economic Commission for Africa), Rayen Quiroga (Economic Commission for Latin America and the Caribbean), Wafa Aboul Hosn (Economic and Social Commission for Western Asia).

The following persons served as members of the Bureau of the Committee of Experts

Amanda Clark (Australia), Carolyn Cahill and Greg Peterson (Canada), P. Bhanumati (India), Sven Kaumanns (Germany), Eduardo de la Torre and Graciela Marquez (Mexico), Sjoerd Schenau (Netherlands), Rachael Milichich (New Zealand), Vivian Ilarina (Philippines), Gerhardt Bouwer (South Africa), Liz McKeown and Neil Wilson (United Kingdom), Anton Steurer (Eurostat), Francesco Tubiello (Food and Agriculture Organization of the United Nations), Jim Tebrake (International Monetary Fund), Myriam Linster and Peter van de Ven (Organisation for Economic Cooperation and Development), Raffaello Cervigni and Sofia Ahlroth (World Bank).

Statistics Division staff

The staff of the Environmental-Economic Accounts Section, Environmental Statistics and Geospatial Information Branch of the United Nations Statistics Division provided secretariat services to the Committee and its Bureau under the overall supervision of Alessandra Alfieri, including, Bram Edens, Elsa Begne, Jessica Ying Chan, Julian Chow, and Marko Javorsek.

Editorial board

The extended Technical Committee on SEEA EA, as mandated by the Committee at its session in June 2018, served as the editorial board for the revision and provided technical guidance on the drafting of the text and expert advice on the resolution of technical issues. The Technical Committee met in 30 meetings between June 2018 and the publication of the white cover publication of the SEEA EA in July 2021.

The Technical Committee was chaired by Anton Steurer (Eurostat) and the members were: Jonathon Khoo, Peter Meadows and Steven May (Australian Bureau of Statistics), François Soulard (Statistics Canada), P. Bhanumati (Ministry of Statistics and Programme Implementation, India), Sjoerd Schenau (Statistics Netherlands), Gerhardt Bouwer (Statistics South Africa), Rocky Harris (Department for Environment, Food and Rural Affairs, United Kingdom), Rosimeiry Portela (Conservation International), Michael Bordt (Economic and Social Commission for Asia and the Pacific and Fisheries and Oceans Canada), Joachim Maes (European Commission, Joint Research Centre), Jan-Erik Petersen (European Environment Agency), Juha Siikamaki (International Union for Conservation of Nature), Francesco Tubiello (Food and Agriculture Organization of the United Nations), James Tebrake (International Monetary Fund), Peter van de Ven (Organisation for Economic Cooperation and Development), Alessandra Alfieri, Jessica Ying Chan, Julian Chow, Bram Edens, Elsa Begne and Marko Javorsek (United Nations Statistics Division), Carl Obst (UNSD Consultant), Lars Hein (Wageningen University, Netherlands), Raffaello Cervigni and Catherine Van Rompaey (World Bank).

Carl Obst was the Editor for the SEEA EA and worked under the guidance of the Technical Committee to synthesize the discussion papers and draft the chapters of the SEEA EA.

Revision working groups

The revision was supported by five working groups. The below lists the area leads and experts that contributed to the work and outputs of the working groups.[1]

Working group 1 on spatial units
Area lead: Sjoerd Schenau (Statistics Netherlands)
Experts: Daniel Juhn, Timothy (Max) Wright and Trond Larsen (Conservation International), David Keith (University New South Wales, Australia), Doug Muchoney and Francesco Tubiello (Food and Agriculture Organization of the United Nations), Edwin Horlings and Patrick Bogaart (Statistics Netherlands), Emily Nicholson (Deakin University, Australia), François Soulard and Mark Henry (Statistics Canada), Jessica Ying Chan (United Nations Statistics Division), Keith Gaddis (National Aeronautics and Space Administration), Michael Bordt (Economic and Social Commission for Asia and the Pacific and Fisheries and Oceans Canada), Roger Sayre (United States Geological Survey).

Working group 2 on ecosystem condition
Area lead: Joachim Maes (European Commission, Joint Research Centre)
Experts: Amanda Driver (South African National Biodiversity Institute), Bálint Czúcz (European Commission, Joint Research Centre), Bethanna Jackson (Victoria University, New Zealand), Emily Nicholson (Deakin University, Australia), Heather Keith (Australian National University & Griffith University, Australia), Marko Javorsek (United Nations Statistics Division), Octavio Pérez Maqueo (Instituto de Ecología, Mexico), Simon Jakobsson (Norwegian Institute for Nature Research).

Working group 3 on ecosystem services
Area lead: Lars Hein (Wageningen University, Netherlands)

[1] All the papers and material related to the working groups can be found here: https://seea.un.org/content/seea-eea-revision-research-areas.

Experts: Alessandra La Notte (European Commission, Joint Research Centre), Anthony Dvarskas (Stony Brook University and ESCAP), Becky Chaplin-Kramer (Stanford University, USA), Benjamin Burkhard (Leibniz Universität Hannover, Germany), Bram Edens and Julian Chow (United Nations Statistics Division), Charles Rhodes (United States Geological Survey), David Barton (Norwegian Institute for Nature Research), Dolf de Groot (Wageningen University, Netherlands), Ilan Havinga (Wageningen University), Jan-Erik Petersen (European Environment Agency), Luke Brander (Brander Environmental Economics), Mahbubul Alam, Maíra Ometto Bezerra and Rosimeiry Portela (Conservation International), Marc Russell (Environmental Protection Agency, USA), Neville Crossman (University of Adelaide and Murray-Darling Basin Authority, Australia), Patricia Balvanera (Universidad Nacional Autónoma de México (UNAM), Mexico), Rocky Harris (Department for Environment, Food and Rural Affairs, United Kingdom), Roy Haines-Young (Fabis Consulting), Sander Jacobs (Research Institute for Nature and Forest (INBO), Belgium), Sjoerd Schenau (Statistics Netherlands), Steven King (United Nations Environment Programme—World Conservation Monitoring Centre).

Working group 4 on individual ecosystem services
Area lead: Rocky Harris (Department for Environment, Food and Rural Affairs, United Kingdom)
Lead authors: Alessandra La Notte (European Commission, Joint Research Centre), Anthony Dvarskas (Stony Brook University and ESCAP), Benjamin Burkhard (Leibniz Universität Hannover, Germany), Bram Edens (United Nations Statistics Division), Carl Obst (UNSD consultant), David Barton (Norwegian Institute for Nature Research), Lars Hein (Wageningen University, Netherlands), Neville Crossman (University of Adelaide and Murray-Darling Basin Authority, Australia), Rosimeiry Portela (Conservation International), Steven King (United Nations Environment Programme—World Conservation Monitoring Centre).
Contributing authors: Alejandro Caparrós (Consejo Superior de Investigaciones Científicas (CSIC), Spain), Beth Fulton and Simon Ferrier (Commonwealth Scientific and Industrial Research Organisation, Australia), Brett Day (University Exeter, United Kingdom), Bruna Grizzetti and Grazia Zulian (European Commission, Joint Research Centre), Brynhildur Davíðsdóttir (University of Iceland), Carlos A Guerra (German Centre for Integrative Biodiversity Research (iDiv)), David Nowak (Forest Service, United Stated Department of Agriculture), Eli Fenichel (Yale University, USA), Emil Ivanov (University of Nottingham, United Kingdom), Gem Castillo (Resource and Environmental Economics Foundation of the Philippines), Giles Atkinson (London School of Economics, United Kingdom), Ilan Havinga (Wageningen University, Netherlands), Jane Turpie (University of Cape Town and Anchor Environmental Consultants, South Africa), Kashif Shaad (Conservation International), Kerry Turner (University of East Anglia, United Kingdom), Laurence Jones and Stefan Reis (Centre for Ecology and Hydrology, United Kingdom), Luke Brander (Vrije Universiteit Amsterdam, Netherlands), Mahbubul Alam (Conservation International), Maíra Ometto Bezerra and Miroslav Honzák (Conservation International), Matthew Agarwala (Bennett Institute for Public Policy, University of Cambridge, United Kingdom), Onil Banerjee (Inter-American Development Bank), Payam Dadvand (ISGlobal, Spain), Peter Elsasser (Thuenen Institute, Germany), Sergio Vallesi (Durham University, United Kingdom), Silvia Cerilli (Food and Agriculture Organization of the United Nations), Silvia Ferrini (University of Siena, Italy and University of East Anglia, United Kingdom), Stoyan Nedkov (Bulgarian Academy of Sciences, Bulgaria), Thomas Randrup (Swedish University of Agricultural Sciences), Timon McPhearson (New School, USA), Tomas Badura (University of East Anglia, United Kingdom and CzechGlobe, Czech Academy of Sciences).

Working group 5 on valuation and accounting treatments
Area lead: Juha Siikamaki (International Union for Conservation of Nature)
Experts: Alejandro Caparros (Consejo Superior de Investigaciones Científicas (CSIC), Spain), Anil Markandya (Basque Centre for Climate Change, Spain), Bram Edens, Herman Smith and Ivo Havinga (United Nations Statistics Division), Burkhard Schweppe-Kraft (Federal Agency for Nature Conservation, Germany), David Barton (Norwegian Institute for Nature Research), Dennis Fixler

(Bureau of Economic Analysis, USA), Eli Fenichel (Yale University, USA), Jane Turpie (University of Cape Town and Anchor Environmental Consultants, South Africa), Jim Tebrake (International Monetary Fund), Joe St Lawrence (Statistics Canada), Matias Piaggio (Tropical Agricultural Research and Higher Education Center (CATIE), Costa Rica), Nicholas Conner (New South Wales Office for the Environment, Australia), Peter Harper (independent expert), Peter van de Ven (Organisation for Economic Cooperation and Development), Rocky Harris (Department for Environment, Food and Rural Affairs, United Kingdom), William Speller (United Nations Environment Programme).

Subgroup on Accounting for Biodiversity in the SEEA EA
Co-chairs: Rosimeiry Portela and Trond Larsen (Conservation International)
Experts: Alessandra Alfieri and Marko Javorsek (United Nations Statistics Division), Amanda Driver (South African National Biodiversity Institute), Anne-Sophie Pellier (Bird Life International), Carl Obst (UNSD consultant), Hedley Grantham (Wildlife Conservation Society), Jillian Campbell and Markus Lehman (Secretariat of the Convention on Biological Diversity), Joel Houdet (University of Pretoria, South Africa), Juha Siikamaki and Thomas Brooks (International Union for Conservation of Nature), Ken Bagstad (United States Geological Survey), Neville Ash and Steven King (United Nations Environment Programme—World Conservation Monitoring Centre), P. Bhanumati (Ministry of Statistics and Programme Implementation, India), Patrick Bogaart (Statistics Netherlands), Rocky Harris (Department for Environment, Food and Rural Affairs, United Kingdom), Simon Ferrier (Commonwealth Scientific and Industrial Research Organisation, Australia).

Working Group on the SEEA EA Indicators
Chair: P. Bhanumati (Ministry of Statistics and Programme Implementation, India)
Experts: Alessandra Alfieri, Bram Edens, Jessica Ying Chan, Julian Chow and Marko Javorsek (United Nations Statistics Division), Anton Steurer (Eurostat), Carl Obst (UNSD consultant), François Soulard (Statistics Canada), Gerhardt Bouwer (Statistics South Africa), HyeJin Kim and Mike Gill (GEOBON Secretariat), Jillian Campbell and Kieran Noonan Mooney (Secretariat of the Convention on Biological Diversity), Juan Pablo Castañeda (World Bank), Juha Siikamaki (International Union for Conservation of Nature), Katia Karousakis and Myriam Linster (Organisation for Economic Cooperation and Development), Ken Bagstad (United States Geological Survey), Nic Bax and Simon Ferrier (Commonwealth Scientific and Industrial Research Organisation, Australia), Ouyang Zhiyun (Chinese Academy of Sciences, China), Rocky Harris (Department for Environment, Food and Rural Affairs, United Kingdom), Shi Faqi (National Bureau of Statistics, China), Sjoerd Schenau (Statistics Netherlands).

Other experts

Experts that drafted text for Chapter 13: Anthony Dvarskas, Gemma Van Halderen and Rikke Munk Hansen (Economic and Social Commission for Asia and the Pacific), Ben Milligan, Coulson Lantz and Jordan Gacutan (University of New South Wales), David Barton (Norwegian Institute for Nature Research), François Soulard and Jennie Wang (Statistics Canada), Juha Siikamaki and Thomas Brooks (International Union for Conservation of Nature), Lars Hein (Wageningen University, Netherlands), Michael Bordt (Economic and Social Commission for Asia and the Pacific and Fisheries and Oceans Canada), Rocky Harris (Department for Environment, Food and Rural Affairs, United Kingdom), Rosimeiry Portela and Trond Larsen (Conservation International), Simon Ferrier (Commonwealth Scientific and Industrial Research Organisation, Australia), Sjoerd Schenau (Statistics Netherlands), Steven King (United Nations Environment Programme—World Conservation Monitoring Centre).

Experts that drafted text for Chapter 14: HyeJin Kim and Mike Gill (Group on Earth Observations Biodiversity Observation Network (GEO BON)), Jillian Campbell (Secretariat of the Convention on Biological Diversity), Nic Bax (Commonwealth Scientific and Industrial Research Organisation, Australia), P. Bhanumati (Ministry of Statistics and Programme Implementation, India), Rocky Harris (Department for Environment, Food and Rural Affairs, United Kingdom).

Designer of the figures in the document: Katharine Strong (Statistics Canada).

Other groups

London Group on Environmental Accounting
The London Group on Environmental Accounting discussed issues related to SEEA Ecosystem Accounting at its meetings between October 2018 and 2020 and provided comments on the draft chapters of the SEEA EA in special webinars between March and August 2020. The London Group was chaired by Nancy Steinbach (Statistics Sweden) until October 2020 and Sven Kaumanns (Federal Statistical Office of Germany) since then.

The following experts prepared papers related to the SEEA EA during the meetings of the London Group in 2018, 2019 and 2020: Aija Kosk (Estonian University of Life Sciences), Aldo Femia (ISTAT, Italy), Alessandra La Notte, Alexandra Marques, Joachim Maes and Sara Vallecillo (Joint Research Centre of the European Commission), Amanda Driver and Aimee Ginsburg (South African National Biodiversity Institute), Anton Steurer (Eurostat), Argo Ronk, Grete Luukas, Kaia Oras, Kätlin Aun, and Veiko Adermann (Statistics Estonia), Avneet Kaur and P. Bhanumati (Ministry of Statistics and Programme Implementation, India), Ben Milligan (University of New South Wales), Brendan Mackey and Heather Keith (Griffith University, Australia), Carl Obst (IDEEA Group), Charles Rhodes (U.S. Environmental Protection Agency), David Barton, Megan Nowell and Zofie Cimburova (Norwegian Institute for Nature Research), David Keith (University New South Wales, Australia), David Lindenmayer and Michael Vardon (Australian National University, Australia), Edwin Horlings, Patrick Bogaart and Sjoerd Schenau (Statistics Netherlands), Francesco Tubiello and Silvia Cerilli (Food and Agriculture Organization of the United Nations), François Soulard (Statistics Canada), Gerhard Bouwer (Statistics South Africa), Irene Alvarado Quesada (Central Bank of Costa Rica), Iulie Aslaksen, Margrete Steinnes and Per Arild Garnåsjordet (Statistics Norway), Jane Turpie (University of Cape Town and Anchor Environmental Consultants, South Africa), Jan-Erik Petersen and Jana Tafi (European Environment Agency), Jessica Ying Chan (UN Statistics Division), Jonathon Khoo, Peter Meadows, Steve May and Suzi Bond (Australian Bureau of Statistics), Juan Pablo Castañeda and Sofia Ahlroth (World Bank), Kaja Lotman (Estonian Environmental Board), Katrin Vaher and Üllas Ehrlich (Tallinn University of Technology), Ken Bagstad (US Geological Service), Laurence Jones and Rocky Harris (Department for Environment, Food and Rural Affairs, UK), Luis Miguel Galindo Paliza (consultant for the NVACES Mexico project), Masayuki Sato (Kobe University, Japan), Raúl Figueroa Díaz (INEGI Mexico), Rikke Munk Hansen (UN Economic and Social Commission for Asia and the Pacific), Rintaro Yamaguchi (National Institute for Environmental Studies, Japan), Roger Sayre (United States Geological Survey), Steven King (UNEP-WCMC), Takashi Hayashi (Ministry of Agriculture, Forestry and Fisheries, Japan), Trond Larsen (Conservation International), Wafa Aboul Hosn (UN Economic and Social Commission for Western Asia).

UN Regional Commissions
Regional commissions played an important role in engaging with countries. In particular, the following people provided support to the revision process: Anthony Dvarskas, Gemma Van Halderen and Rikke Munk Hansen (Economic and Social Commission for Asia and the Pacific), Rayen Quiroga and Rolando Ocampo (Economic Commission for Latin America and the Caribbean).

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
Regular meetings with the Values Assessment experts of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) were organized during the revision process.

The engagement was mainly through the co-chairs of the IPBES values assessment, including Brigitte Baptiste (Universidad EAN, Colombia), Michael Christie (Aberystwyth University, UK), Patricia Balvanera (Universidad Nacional Autónoma de México), and Unai Pascual (Basque Centre for Climate Change, Spain).

Natural Capital Accounting and Valuation of Ecosystem Services (NCAVES)
The following experts from the NCAVES five project countries have provided support to the revision through their comments and testing of the approaches: Aimee Ginsburg, Amanda Driver, Andrew Skowno, Anisha Dayaram, Nancy Job and Nokuthula Mahlangu (South African National Biodiversity Institute, South Africa), Amos Pérez Eduardo de la Torre, Arturo Blancas, Carmen Reyes, Federico Gonzalez, Francisco Guillen, Jose Luis Ornelas, Paloma Merodio, Raul Figueroa, Rodolfo Orozco and Vincente Diaz Nuñez (INEGI Mexico), Brenda Mphakane, Gerhardt Bouwer, Riaan Grobler, Rob Anderson and Robert Parry (Statistics South Africa), Bruna Stein Ciasca, Christianne Maroun, Jaqueline Coelho Visentin, Julian Equihua, Luis-Miguel Galindo, María Zorrilla, Melanie Kolb, Miquel Equihua, Monica Sharma, Octavio Pérez Maqueo, Salvador Sanchez Colón, Saul Basurto and Sonia Arora (UN consultants), Cesar Rodriguez, Georgina Alcantar (SEMARNAT, Mexico), Claudio Stenner, Fernando Peres Diaz, Ivone Lopes Batista, Leonardo Lima Bergamini, Maria Luisa Pimenta, Michel Vieira Lapip, Rebeca de La Rocque Palis and Therence Paoliello de Sarti (IBGE, Brazil), Gretchen Daily (Stanford University), Han Mingchen (Guangxi Zhuang Autonomous Region Bureau of Statistics, China), Ian Batemen (University of Exeter), Jane Turpie and Joshua Weiss (Anchor Environmental), Jeanne Nel (Wageningen Environmental Research), Krishna Kumar Tiwari, Kuwar Alok Singh Yadav, P. Bhanumati, Rakesh Maurya, Ruchi Mishra, Sudeepta Ghosh (Ministry of Statistics and Programme Implementation, India), Ouyang Zhiyun (Chinese Academy of Sciences), Qiu Qiong and Shi Faqi (National Bureau of Statistics, China), Stephen Polasky (University of Minnesota).

Global consultations

There were two formal global consultations during the revision process. The first one on individual chapters between March and August 2020,[2] and the second one of the complete draft of the SEEA EA between October and November 2020.[3]

The following countries participated in the global consultations. In many cases, several national agencies contributed to a consolidated contribution or submitted separate contributions, they all however represent a common national position on the global consultation.
Albania, Armenia, Australia, Azerbaijan, Belarus, Belgium, Bolivia, Botswana, Brazil, Bulgaria, Burundi, Cameroon, Canada, China, Colombia, Croatia, Czech Republic, Denmark, Ecuador, Estonia, Ethiopia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Iran (Islamic Republic), Iraq, Ireland, Italy, Jordan, Kenya, Latvia, Lesotho, Lithuania, Malaysia, Mauritius, Mexico, Mongolia, Morocco, Mozambique, Myanmar, Nepal, Netherlands, New Zealand, Norway, Peru, Philippines, Poland, Qatar, Romania, Saudi Arabia, Senegal, Slovakia, Slovenia, South Africa, Spain, State of Palestine, Sudan, Suriname, Sweden, Switzerland, Thailand, Tunisia, United Kingdom, United States, Uruguay, Venezuela, Viet Nam, Zambia and Zimbabwe

The following organizations participated in the global consultations: Capitals Coalition, Conservation International, Ducks Unlimited Canada, Ecological Accounting Chaire (Chaire de Comptabilité Ecologique), European Central Bank, European Commission (Directorate-General for the Environment, Eurostat, Joint Research Centre), European Environment Agency, Food and Agriculture

[2] For details see: https://seea.un.org/content/global-consultation-individual-chapters.

[3] For details see: https://seea.un.org/content/global-consultation-complete-draft.

Organization of the United Nations, Gaborone Declaration for Sustainability in Africa, Global Footprint Network,
Group on Earth Observations Biodiversity Observation Network, Intemerate Working group,
International Monetary Fund, International Union for the Conservation of Nature, Organisation for Economic Cooperation and Development, Secretariat of the Convention on Biological Diversity, The Eastern Africa Statistical Training Centre, United Nations Development Programme, United Nations Economic Commission for Latin America and the Caribbean, United Nations Environment Programme, United Nations Environment Programme—World Conservation Monitoring Centre, United Nations Statistics Division, World Bank, World Economic Forum Beijing Representative Office, World Tourism Organization.

The following individual experts participated in the global consultations: Adrien Comte (Centre international de recherche sur l'environnement et le développement (CIRED), France), Aldo Ravazzi Douvan, Antonia Oriani, Greti Lucaroni, Karima Oustadi (Sogesid T.A. – Ministry of Environment of Italy – Technical Secretariat of the Italian Natural Capital Committee), Alejandro Caparrós, Jose L. Oviedo and Pablo Campos (Consejo Superior de Investigaciones Científicas (CSIC), Spain), Alison Fairbrass and Paul Ekins (Institute for Sustainable Resources, University College London, United Kingdom), Anna Richards, Becky Schmidt, Beth Fulton, Gabriela Scheufele, Richard Mount, Simon Ferrier and Suzanne Prober (Commonwealth Scientific and Industrial Research Organisation, Australia), Ben Milligan (University of New South Wales, Australia), Christopher Martin (Whitehorse Training, United Kingdom), David MacDonald (Chair, Expert Group on Resource Management), Eli Fenichel (Yale University, USA), G. Grilli, R. K. Turner, S. Ferrini and T. Badura, (University of East Anglia, United Kingdom), Heather Keith and Michael Vardon (Australian National University and Griffith University, Australia), Jana Tafi (expert in environmental accounting and assessments), Jane Turpie (University of Cape Town and Anchor Environmental Consultants, South Africa), John Finisdore (Sustainable Flows, Australia and USA), John Finisdore, Mark Eigenraam and Reiss McLeod (IDEEA Group, Australia), John Maughan (Green Growth Knowledge Platform), Julian Hilton (Aleff Group, United Kingdom and Chair, Sustainable Development Goals Working Group, Expert Group on Resource Management, UNECE Geneva), Laurence Jones (United Kingdom Centre for Ecology & Hydrology), Leon Braat (Editor-in-Chief, for Elsevier journal Ecosystem Services), Louise Willemen (University of Twente, Netherlands), Melanie Kolb (Institute of Geography, Universidad Nacional Autónoma de México (UNAM), Mexico), Robert Johnston (Clark University, USA), Sara Ortiz (Universidad Rafael Landívar, Guatemala), Solen Le Clec'h (Wageningen University, Netherlands), Steven Broekx (Flemish Institute for Technological Research (VITO), Belgium), Thomas Ochuodho (University of Kentucky, USA), Walter J. Radermacher (La Sapienza University, Rome).

Meetings and workshops

The following meetings and workshops were held to encourage engagement, build on expertise of different communities, and allow for detailed discussions on issues that were required to make substantive progress on technical matters:

- 24-26 April 2018 (Bonn): Expert Workshop on Valuation for Ecosystem Accounting
- 18-20 June 2018 (Glen Cove, NY): Forum of Experts on SEEA Experimental Ecosystem Accounting
- 21-22 June 2018 (New York): Thirteenth Meeting of the UN Committee of Experts on Environmental-Economic Accounting
- 1-4 October 2018 (Dublin): Meeting of the London Group on Environmental Economic Accounting
- 28-29 November 2018 (Paris): Expert meeting on Spatial Areas and Ecosystem Condition

- 30 November 2018 (Paris): Strategic meeting on accounting for biodiversity and ecosystems with IUCN and selected biodiversity experts
- 22-24 January 2019 (New York): Expert Meeting on Advancing the Measurement of Ecosystem Services for Ecosystem Accounting
- 24-25 June 2019 (New York): Fourteenth Meeting of the UN Committee of Experts on Environmental-Economic Accounting
- 26-27 June 2019 (Glen Cove, NY): Forum of Experts on SEEA Experimental Ecosystem Accounting
- 28-29 June 2019 (Glen Cove, NY): Technical Expert Meeting on advancing the SEEA EEA Revision
- 1-3 October 2019 (Washington DC): Meeting of the Advisory Expert Group on National Accounts
- 7-10 October 2019 (Melbourne): Meeting of the London Group on Environmental Accounting
- 4-8 November 2019 (Paris): OECD Working Parties on Financial Statistics and National Accounts
- 13 March 2020 (virtual): Meeting of the London Group on the general context of the revision
- 16-18 March 2020 (virtual): Technical Meeting on Valuation and Accounting for the revised SEEA EEA
- 21 April 2020 (virtual): Meeting of the London Group on draft Chapters 3-5
- 4 June 2020 (virtual): Presentation of the revision process and engagement to African countries as part of the African Community of Practice on Natural Capital Accounting
- 18 June 2020 (virtual): Meeting of the London Group on draft Chapters 8-11
- 23-24 June 2020 (virtual): Virtual Forum of Experts on SEEA Experimental Ecosystem Accounting – Session 1: Ecosystem extent and condition
- 6-9 July 2020 (virtual): Fifteenth Meeting of the UN Committee of Experts on Environmental-Economic Accounting
- 14-15 July 2020 (virtual): Virtual Forum of Experts on SEEA Experimental Ecosystem Accounting – Session 2: Valuation and accounting treatments
- 18 August 2020 (virtual): Meeting of the London Group on draft Chapters 6-7
- 24-25 August 2020 (virtual): Virtual Forum of Experts on SEEA Experimental Ecosystem Accounting – Session 3: Ecosystem services
- 5-12 October 2020 (virtual): Meeting of the London Group on Environmental Accounting
- 28 October 2020 (virtual): Presentation of the revision process and engagement to Latin American countries as part of the Latin American Community on Natural Capital Accounting
- 9-10 November 2020 (virtual): Virtual Forum of Experts on SEEA Experimental Ecosystem Accounting – Session 4: Thematic accounts and indicators
- 16-18 November 2020 (virtual): Extraordinary Meeting of the UN Committee of Experts on Environmental-Economic Accounting
- 4 February 2021 (virtual): High-level webinar on the finalization of the revision of the SEEA EA for Latin American and Caribbean countries co-organized by ECLAC and UNSD

Abbreviations and acronyms

ABNJ	Areas Beyond National Jurisdiction
BIOFIN	Biodiversity Finance Initiative
BSU	Basic spatial unit
CBD	Convention on Biological Diversity
CEA	Classification for environmental activities
CICES	Common International Classification of Ecosystem Services
COED	Costs of environmental degradation
COICOP	Classification of Individual Consumption by Purpose
CPC	Central Product Classification
CV	Contingent valuation
DPISR	Drivers – pressure – state – impact – response
EAA	Ecosystem accounting area
EBVs	Essential Biodiversity Variables
ECT	Ecosystem condition typology
EE-IOT	Environmentally-extended input-output tables
EESVs	Essential Ecosystem Services Variables
EEZ	Exclusive Economic Zone
EFG	IUCN GET Ecosystem Functional Groups
EGSS	Environmental goods and services sector
ESCAP	Economic and Social Commission for Asia and the Pacific
ET	Ecosystem type
FDES	Framework for the Development of Environment Statistics
GDP	Gross Domestic Product
GEO BON	Group on Earth Observations – Biodiversity Observation Network
GEO EO4EA	Group on Earth Observations – Earth Observation for Ecosystem Accounting
GHG	Greenhouse gas
GIS	Geographic information systems
GSGF	Global Statistical Geospatial Framework
GVA	Gross Value Added
IAEG-SDGs	Inter-Agency and Expert Group on SDG Indicators
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
ISIC	International Standard Industrial Classification
IUCN	International Union for the Conservation of Nature
IUCN GET	IUCN Global Ecosystem Typology
LCCS	FAO Land Cover Classification System
LDN	Land degradation neutrality
LULUCF	Land use, land use change and forestry
MA	Millennium Assessment
MAES	Mapping and Assessment of Ecosystems and their Services
MST	Measuring the Sustainability of Tourism
NCP	Nature’s Contribution to People
NDC	Nationally Determined Contributions
NDP	Net Domestic Product
NESCS	National Ecosystem Service Classification System
NPV	Net present value
NSDI	National Spatial Data Infrastructure
NSO	National statistical office
PES	Payments for ecosystem services

PSUT	Physical supply and use tables
SBA	Service benefitting areas
SDGs	Sustainable Development Goals
SEEA AFF	SEEA for Agriculture, Forestry and Fisheries
SEV	Simulated Exchange Value
SNA	System of National Accounts
SOC	Soil organic carbon
SPA	Service providing areas
SUT	Supply and use table
TCM	Travel cost method
TEEB	The Economics of Ecosystems and Biodiversity initiative
TEV	Total Economic Value
UNCCD	United Nations Convention to Combat Desertification
UNCEEA	United Nations Committee of Experts on Environmental-Economic Accounting
UNEP	United Nations Environment Programme
UNEP-WCMC	United Nations Environment Programme World Conservation Monitoring Centre
UNFCCC	United Nations Framework Convention on Climate Change
UNSC	United Nations Statistical Commission
UNSD	United Nations Statistics Division
WTA	Willingness to accept a payment
WTP	Willingness of individuals to pay

SECTION A: Introduction and overview

Section Overview

The *System of Environmental-Economic Accounting—Ecosystem Accounting* (SEEA EA) is a spatially-based, integrated statistical framework for organizing biophysical information about ecosystems, measuring ecosystem services, tracking changes in ecosystem extent and condition, valuing ecosystem services and assets and linking this information to measures of economic and human activity. It was developed to respond to a range of policy demands and challenges with a focus on making visible the contributions of nature to the economy and people.

The United Nations Statistical Commission (UNSC) at its fifty-second session in March 2021 adopted SEEA EA chapters 1-7 describing the accounting framework and the physical accounts as an international statistical standard; recognised that SEEA EA chapters 8-11 of the SEEA EA describe internationally recognised statistical principles and recommendations for the valuation of ecosystem services and assets in a context that is coherent with the concepts of the System of National Accounts for countries that are undertaking valuation of ecosystem services and/or assets; and noted SEEA EA chapters 12-14 were noted as describing the applications and extensions of ecosystem accounting.

The SEEA EA complements the measurement of the relationship between the environment and the economy described in the *System of Environmental-Economic Accounting 2012—Central Framework* (SEEA Central Framework) (United Nations et al., 2014a). The SEEA, encompassing the SEEA Central Framework and the SEEA EA, provides a system that complements the System of National Accounts (SNA) using accounting principles to integrate physical and monetary measures concerning the environment in a way that allows for comparison to the data from the national accounts.

Chapter 1 provides an overview of the SEEA EA concerning the context for its development, the connections to other measurement frameworks and initiatives and considerations in implementation. Chapter 2 summarizes the ecosystem accounting framework placing in context information on ecosystem extent, ecosystem condition, ecosystem services and monetary values of ecosystem services and assets.

SEEA EA applies the accounting principles of the *System of National Accounts 2008* (2008 SNA) (United Nations et al., 2010). In the context of monetary valuation, the SEEA EA applies the SNA concept of exchange values. While estimates based on this value concept are useful in many contexts, there are some limitations. For example, they do not include the monetary value of the wider social benefits of ecosystems, including their non-use values, which some users may find useful.

More generally, monetary values will not fully reflect the importance of ecosystems for people and the economy. Assessing the importance of ecosystems will therefore require consideration of a wide range of information beyond data on the monetary value of ecosystems and their services. This will include data on the biophysical characteristics of ecosystems and data on the characteristics of the people, businesses and communities that are dependent on them.

The SEEA EA is a system conceived as an integrated, internally consistent series of accounts. Its design is such that it can be implemented equally well in parts, i.e., the implementation can be flexible and modular. Indeed, the progressive and staged development of the range and detail of the ecosystem accounts is likely an appropriate implementation strategy. Generally, the compilation of accounts in monetary terms will require the use of data in physical terms. It is recommended that when monetary accounts are released, the associated data in physical terms are also released, for example concerning changes in ecosystem extent and condition. This will aid interpretation and application of the monetary data in policy and decision making. Interpretation and analysis of ecosystem accounting data will also be supported through the use of other data such as concerning environmental protection expenditure, industry value added, employment and population.

1 Introduction

1.1 Context for SEEA Ecosystem Accounting

1.1 It is well established that healthy ecosystems and biodiversity are fundamental to supporting and sustaining our wellbeing, our communities and our economies. However, our environment is under pressure and there are consequential risks that we face in securing and improving our livelihoods. These challenges have been recognised at local, national and global levels. Global responses have been articulated clearly in the Sustainable Development Goals[4] and other global agreements such as the Paris Agreement[5] on limiting the effects of climate change and the Global Biodiversity Framework[6] to conserve biodiversity.

1.2 In addition, there has been growing recognition that the degradation of nature is not purely an environmental issue requiring environmental policy responses; economic and social policy responses are also required. Thus, decision makers across all sectors need to consider their environmental context and the associated dependencies and impacts. Consequently, establishing agreed and ongoing measurement of changes in the state of the environment and the relationship to economic and other human activity is central to ensuring that ecosystems and biodiversity are mainstreamed in decision-making processes, including those concerning our economic and financial systems.

1.2 What is SEEA Ecosystem Accounting?

1.2.1 Introduction

1.3 The *System of Environmental-Economic Accounting—Ecosystem Accounting* (SEEA EA) is a spatially-based, integrated statistical framework for organizing biophysical information about ecosystems, measuring ecosystem services, tracking changes in ecosystem extent and condition, valuing ecosystem services and assets and linking this information to measures of economic and human activity. SEEA EA was developed by a multidisciplinary group of experts to respond to a range of policy demands and challenges with a focus on making visible the contributions of nature to the economy and people, and on better recording the impacts of economic and other human activity on the environment. To this end, ecosystem accounting incorporates a wider range of benefits to people than captured in standard economic accounts and provides a structured approach to assessing the dependence and impacts of economic and human activity on the environment.

1.4 The SEEA EA complements the measurement of the relationship between the environment and the economy described in the SEEA Central Framework. The SEEA EA's data on ecosystems can be combined with the data from the SEEA Central Framework accounts on environmental pressures, individual resource stocks and environmental responses in the form of expenditures, taxes and subsidies, to provide a comprehensive picture of the environmental-economic relationship.

[4] United Nations General Assembly, Seventieth Session, Resolution Adopted on 25 September 2015, A/RES/70/1. https://undocs.org/A/RES/70/1

[5] United Nations Framework Convention on Climate Change, Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13December 2015, FCCC/CP/2015/10/Add.1. https://undocs.org/FCCC/CP/2015/10/Add.1

[6] Expected to be adopted at the Fifteenth meeting of the Conference of the Parties (COP 15) to the CBD in Kunming, China in October 2021.

1.5 The SEEA EA applies the accounting principles of the 2008 SNA, the statistical framework for the measurement of the economy. By applying national accounting principles, the SEEA framework allows for a unique integration of environmental and economic data to support decision making. The harmonization of these data is intended to contribute to mainstreaming the use of environmental data on ecosystems in economic decision making and to supporting the use of economic data in environmental decision making.

1.6 The use of an accounting approach takes advantage of the inherent structure of accounts wherein both stocks and flows are part of a single recording system. In this context, the basic accounting principles are applied to the organisation of data in both physical and monetary terms to provide an integrated, coherent and consistent set of data. Further, the use of an accounting approach envisages comparable, regular and ongoing measurement.

1.2.2 Coverage and interpretation of the SEEA EA

1.7 The SEEA EA reflects the integration of the latest knowledge, methods and techniques in the measurement of ecosystems. Nonetheless, it is recognised that there are challenges in implementation and interpretation that will require ongoing attention. It is expected that the knowledge about ecosystem accounting, as well as understanding of the data sources and methods used to compile accounts, will evolve over time as a result of widespread implementation of these accounts. Consequently, as with all statistical methodology documents, it will be necessary to refine and revise the SEEA EA in the future and to continue the development of technical guidance and related material to support implementation and interpretation.

1.8 The SEEA EA is comprehensive in its coverage of ecosystems, including all terrestrial, freshwater, marine and subterranean ecosystem realms. Further, in describing the connection between ecosystems and economic and human activity, it has a deliberate focus on ecosystem services reflecting the many direct and indirect uses of ecosystems. However, this coverage does not encompass all of the potential connections with ecosystems. Specifically, the measurement scope of the SEEA EA does not directly encompass the importance of ecosystems arising from their ongoing existence and only captures a portion of significant cultural and spiritual relationships we have with the environment.

1.9 In addition, in the context of monetary valuation, the SEEA EA applies the concept of exchange values in line with standard economic accounting principles and to support comparison to standard economic and financial data. While these values are useful in many contexts, they will not be equivalent to monetary values that incorporate the wider social benefits of ecosystems. Measurement of the economic value of these social benefits, while important, goes beyond the scope of the SEEA EA. Chapter 12 discusses some aspects of the links between monetary values in ecosystem accounting and other monetary values.

1.10 More generally, it is emphasised that monetary values from the accounts and the wider economic values just described will not fully reflect the importance of ecosystems for people and the economy. Assessing the importance of ecosystems will therefore require consideration of a wider range of information beyond data on the monetary value of ecosystems and their services. This will include data on the biophysical characteristics of ecosystems and data on the characteristics of the people, businesses and communities that are dependent on them.

1.11 While the SEEA EA does not incorporate all data that may be relevant in assessing the relationship between the environment and economic and human activity, it provides a structured framework for organising data that can support further analysis and place various perspectives in context.

1.2.3 Implementation of the SEEA Ecosystem Accounting

1.12 The SEEA EA is a system conceived as an integrated, internally consistent series of accounts. At the same time, its design is such that it can be implemented equally well in parts, i.e., the implementation can be flexible and modular. Indeed, the progressive and staged development of the range and detail of the ecosystem accounts is likely an appropriate implementation strategy. Depending on the specific environmental and economic context, a country may choose to implement only a selection of the accounts or to compile accounts for selected regions within their country. For example, countries may decide to only produce accounts in physical terms and not in monetary terms.

1.13 Particularly relating to the compilation of accounts in monetary terms, some compilers may be concerned that the data requirements and methodological assumptions are too significant to justify their compilation as part of official statistics. At the same time, there may be substantive demand for well-defined and comparable estimates in monetary terms for use in policy and analysis. Given these potentially competing considerations, it will be appropriate to focus work on compiling accounts that are both of high relevance for decision making and for which data and estimation approaches are sufficiently advanced.

1.14 National Statistical Offices (NSOs) operate in different contexts with different ranges of responsibility. Depending on the national context there may be opportunities to compile ecosystem accounts using collaborative approaches taking advantages of the strengths of NSOs in combination with the expertise of other agencies and research organisations. Since ecosystem accounting has a multi-disciplinary scope, the use of multi-institutional approaches to implementation is appropriate.

1.15 Where accounts in monetary terms are compiled, it is recommended that associated data in physical terms, for example concerning changes in ecosystem extent and condition and flows of ecosystem services in physical terms, are also released to aid interpretation and application of the monetary data in policy and decision making. Further, interpretation and analysis of ecosystem accounting data will be supported through the use of other data such as environmental protection expenditure, industry value added, employment and population.

1.16 To support implementation, application and interpretation of the ecosystem accounts, a range of technical guidance is available on the SEEA website.[7] This guidance will be progressively expanded as experience on the compilation and use of ecosystem accounts advances.

1.3 The statistical context for ecosystem accounting

1.3.1 Historical background of the SEEA

1.17 Ecosystem accounting has arisen out of work on environmental accounting initiated by the international community of official statisticians under the direction of the United Nations Statistical Commission. Work on the SEEA started in the 1980s in response to the demand for internalizing natural resource depletion and degradation into macro-economic accounting and culminated with the release of the *Handbook of National Accounting: Integrated*

[7] https://seea.un.org/ecosystem-accounting

Environmental and Economic Accounting (SEEA 1993) (United Nations, 1993). This release responded to the policy demands of Agenda 21, the outcome document of the United Nations Conference on Environment and Development,[8] which included a call for countries to implement the SEEA.

1.18 Based on the experimentation in countries, the SEEA 1993 was subsequently updated in 2003 through a process of expert meetings and wide consultation led by the London Group on Environmental Accounting, one of a number of city groups established to advance methodologies and practices by the United Nations Statistical Commission.[9] The resulting *Handbook of National Accounting: Integrated Environmental and Economic Accounting 2003* (SEEA 2003) (United Nations et al., 2003) presented a number of different methodological approaches and a range of country examples showing varying country practices. The SEEA 2003 was not formally adopted as an internationally agreed statistical framework. Nonetheless, it provided a well-accepted and robust set of approaches for the compilation of various environmental-economic accounts.

1.19 Recognizing the critical importance of information on the environment and its relationship with the economy, the United Nations Statistical Commission established the Committee of Experts on Environmental-Economic Accounting (UNCEEA) in 2007 with the primary objective to mainstream environmental-economic accounting as part of official statistics. It subsequently endorsed a second revision process which led to the development of the *System of Environmental-Economic Accounting 2012—Central Framework* (SEEA Central Framework) (United Nations et al., 2014a). The SEEA Central Framework was adopted "as the initial version of the international standard for environmental-economic accounts" by the Statistical Commission at its forty-third session in March 2012.[10] It describes a standardised approach to accounting for a variety of physical flows, physical and monetary measures of individual environmental assets and environmental transactions.

1.3.2 Development of the SEEA Ecosystem Accounting

1.20 During the development of the SEEA Central Framework, a range of highly relevant topics were identified for which further research was needed or which were new to the statistical community and required further testing and experimentation. These topics primarily concerned accounting for ecosystems and their degradation. Thus, the Statistical Commission supported the development of the *System of Environmental-Economic Accounting 2012—Experimental Ecosystem Accounting* (SEEA 2012 EEA) (United Nations et al., 2014b) to complement the SEEA Central Framework.

1.21 In March 2013, the SEEA 2012 EEA was endorsed by the Statistical Commission at its forty-fourth session as an important step in the development of an integrated statistical framework for organizing biophysical information, measuring ecosystem services, tracking changes in ecosystem assets and linking this information to economic and other human activity. The Statistical Commission also encouraged the use of SEEA 2012 EEA by international and regional agencies and countries.[11] At that time, it was not adopted as an internationally agreed statistical standard and was given the label "experimental" because of the novelty of the

[8] Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992. Volume 2, Proceedings of the Conference. A/CONF.151/26/Rev.1 (Vol.II). https://undocs.org/A/CONF.151/26/Rev.1(Vol.II)

[9] For more information see: https://seea.un.org/content/london-group-environmental-accounting

[10] United Nations Statistical Commission, Report on the forty-third session, E/2012/24. https://undocs.org/E/2012/24

[11] United Nations Statistical Commission, Report on the forty-fourth session, E/2013/24. https://undocs.org/E/2013/24

conceptual framework from a statistical perspective and the lack of agreed measurement methods, including testing of them.

1.22 While the ecosystem accounting framework described in SEEA 2012 EEA was novel, it reflected the integration of many well-established areas of expertise including statistics and national accounting, ecology and natural science, geography and geo-spatial measurement and environmental economics. By providing a conceptual basis on which these disciplines could exchange and share ideas, the SEEA 2012 EEA facilitated a rapid growth in the development and testing of ecosystem accounting. In support of this level of activity, in December 2017, the United Nations Statistics Division released the *Technical Recommendations in support of the SEEA EEA* (Technical Recommendations) (United Nations, 2019). This publication summarized the state of knowledge and practice on ecosystem accounting at that time and further supported ongoing development and testing of methods.

1.23 Given the level of interest, testing and experimentation, in June 2017 the UNCEEA determined that a revision of the SEEA 2012 EEA was appropriate with the ambition that as many aspects of ecosystem accounting as possible should be elevated to an international statistical standard by 2021. The revision process was endorsed by the Statistical Commission at its forty-ninth session in March 2018.[12]

1.24 The revision process was carried out under the auspices of the UNCEEA with technical leadership provided by the SEEA EEA Technical Committee. Four key revision areas were established, namely (i) spatial units; (ii) ecosystem condition; (iii) ecosystem services; and (iv) monetary valuation and accounting. Five working groups led research and discussion across these research areas with work commencing in early 2018. Twenty-three primary discussion papers, four background papers, and numerous issue notes were drafted for review by various technical experts across the disciplines noted above. Using this content and feedback, chapters were drafted for consideration by the SEEA EEA Technical Committee. The chapters were released for two rounds of global consultation through 2020. A novelty of this process was the active engagement with many expert communities, global environmental and sustainability initiatives, and the hosting of various in-person and virtual forums on ecosystem accounting. This breadth of engagement enriched the design and content of the ecosystem accounting framework and provided the basis for its ongoing implementation and development.[13]

1.4 The conceptual approach of the SEEA Ecosystem Accounting

1.25 The general approach to ecosystem accounting in recording stocks and flows concerning ecosystems has been described in a range of documents in varying ways. SEEA-focused research (e.g., Vanoli, 1995) and research concerning extensions to the SNA (e.g., Council, 1999) has considered the type of accounting described in SEEA EA. Of particular note is work on wealth accounting advanced by both the World Bank (2018) and the UNEP (2018). While most focus in this work has been on measuring the wealth of natural resources, the extension to capture a wider range of benefits from the environment, including ecosystem services, is well established in the wealth accounting literature.[14]

[12] United Nations Statistical Commission, Report on the forty-ninth session, E/2018/24. https://undocs.org/E/2018/24

[13] The materials created and discussed through the revision process can be accessed at https://seea.un.org/content/seea-experimental-ecosystem-accounting-revision

[14] The literature on wealth accounting is rich with more recent work including Arrow et al. (2012); Barbier (2013); Dasgupta (2009); Fenichel & Abbott (2014).

1.26 In addition to these economic and accounting connections, the ecosystem accounting framework adapts the concepts developed on ecosystem services measurement, such as the cascade model (Haines-Young & Potschin-Young, 2010), and the core ecosystem accounting model can be placed within the conceptual framing of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Díaz et al., 2015). In its spatial approach to considering ecosystems, the ecosystem accounting framework builds on extensive work on the classification, mapping and delineation of ecosystems and their services.[15] In the measurement of ecosystem condition, there are clear connections to long-standing ecological theory and measurement.[16] Overall, the underlying logic and conceptual basis for ecosystem accounting should be considered to be well established.

1.27 The essence of ecosystem accounting lies in representing the biophysical environment in terms of distinct spatial areas each representing a specific ecosystem type. Ecosystem types include, for example, forests, grasslands, wetlands, cultivated areas, urban areas, rivers, coastal dunes, coral reefs and deep sea floors. Each spatial area of a specific ecosystem type is, for accounting purposes, treated as an ecosystem asset. Each ecosystem asset is accounted for in a manner that is broadly analogous to the treatment of produced assets in the SNA, such as dwellings, in which there is an underlying stock of capital (e.g., a house with specific characteristics (such as a number of bedrooms) and of a given condition) and an associated flow of services (e.g., owner-occupied housing services and rental income).

1.28 Thus, in practice, ecosystem accounting involves recording over an accounting period (i) the stock and change in stock of each ecosystem asset (encompassing entries for ecosystem enhancement and degradation); and (ii) flows from that asset in the form of ecosystem services. The flows of ecosystem services in any accounting period will be related to the ecosystem type, its size or extent and its condition or health; and to factors determining levels of use such as population. While there are conceptual and definitional issues that require explanation, this general framing remains applicable throughout the SEEA EA. Chapter 2 provides a more detailed overview of the ecosystem accounting framework.

1.29 The principles for recording stocks and flows, that are applied in ecosystem accounting can be used to organize data expressed in both physical and monetary terms. The use of common principles encourages the combined use of physical and monetary data. For entries in monetary terms, the SEEA EA applies the concept of exchange values wherein ecosystem services and ecosystem assets are valued at the prices at which they are exchanged, or would be exchanged if markets were present. This approach supports comparison of ecosystem accounting monetary values with those recorded in conventional economic and financial accounts.

1.30 However, there is a range of other approaches to economic valuation of the environment that will generally provide larger monetary values and will be suited to different analytical questions and policy contexts. Therefore, the SEEA EA monetary values should not be considered to provide, and do not intend to estimate, a complete "value of nature." Further, in many decision-making contexts it will be essential to use physical data, for example on the changing condition of ecosystems, either directly or to support interpretation of monetary values. Physical data can also support discussion of non-monetary environmental values which will be significant in many contexts.

1.31 The ecosystem accounting framework provides the basis for the compilation of various ecosystem accounts. Five ecosystem accounts are described: (i) the ecosystem extent

[15] For example, Burkhard & Maes (2017); D. A. Keith et al. (2020); Sayre et al. (2020).

[16] For example, Andreasen et al. (2001); Holling (1973); Karr (1981); Leopold (1949); Wheeler (2002).

account; (ii) the ecosystem condition account; (iii) the ecosystem services flow account in physical terms; (iv) the ecosystem services flow account in monetary terms; and (v) the monetary ecosystem asset account. There is also a range of related accounts, complementary presentations and applications, including thematic accounts and indicators. All of these accounts and related outputs are introduced in Chapter 2 and described in detail in relevant chapters.

1.32 The framework described in the SEEA EA refines the original conceptual framework for ecosystem accounting described in SEEA 2012 EEA. In many areas, the revisions provide additional explanations and clarifications. However, there were some areas where reinterpretation or re-expression of the original framework reflecting the outcomes of ongoing discussions and conversations with a wider range of experts. This is particularly evident in the application of concepts concerning ecology and biodiversity and in the discussion on the monetary valuation of ecosystem services and assets. The main areas in which conceptual improvements have been introduced are described in Annex 1.1.

1.5 Connections to other measurement frameworks and initiatives

1.5.1 Introduction

1.33 Ecosystem accounting has a number of key features that allow it to support, complement and extend other measurement frameworks and initiatives. These key features are:

i. Ecosystem accounting is designed to facilitate comparison and integration with the economic data prepared in accordance with the SNA. This leads to the adoption of certain measurement boundaries and valuation concepts which are not systematically applied in other forms of ecosystem measurement.

ii. Ecosystem accounting encompasses accounting for ecosystem assets in terms of both ecosystem extent and condition, and ecosystem services. Commonly, the measurement of ecosystem extent and condition is undertaken quite separately from the measurement of ecosystem services.

iii. Ecosystem accounting encompasses coherent accounting in both physical terms (e.g., hectares, tonnes) and in monetary terms. Through the coherent recording in physical and monetary terms, and coverage of stocks and flows, the ecosystem accounting framework is well suited to the derivation of a wide range of indicators from a single information base and to supporting integrated environmental-economic analyses.

iv. Ecosystem accounting is designed to provide a broad, cross-cutting perspective on ecosystems at a country and/or comprehensive subnational level. Since many ecosystem measurements are conducted at a detailed local level, ecosystem accounting enables granular data to be utilized to produce a richly textured picture of the condition of ecosystems and the services they supply.

v. Ecosystem accounting supports the consistent and comparable recording of data over time and thus provides information on trends in condition indicators (e.g., for grasslands, lakes), the composition of ecosystem types (e.g., rates of conversion from natural to intensively managed ecosystem types), and relationships between changes in the stock of ecosystems and flows of ecosystem services.

1.5.2 *Connection to the SEEA Central Framework*

1.34 As noted in section 1.2, the SEEA EA and the SEEA Central Framework provide collectively a rich and comprehensive framework for the organisation of data on the relationship between the environment and the economy. They have been designed to complement each other and both reflect the application of the accounting principles of the SNA.

1.35 The SEEA Central Framework provides concepts, definitions and classifications to support integrated accounting for physical flows (natural inputs from, and residual flows to, the environment such as water, energy, air emissions and solid waste); environmental transactions and transfers (e.g., environmental taxes, environmental subsidies and environmental protection expenditure); and individual environmental assets (e.g., mineral and energy resources, timber, fish, land, soil and water).

1.36 Connections to ecosystem accounting can be identified in a number of areas. In the context of accounting for physical flows, measures of natural inputs from the environment (for example concerning uncultivated timber resources) will be aligned with measures of ecosystem services, while measures of residual flows (e.g., flows of particulate matter, excess nitrogen) will be related to flows of ecosystem services that concern, for example, air filtration and water purification. Residual flows will also often indicate environmental pressures that can be related to changes in ecosystem condition. There are also connections that can be identified between environmental taxes and subsidies, expenditures on environmental protection and change in ecosystem condition; and between the monetary value of natural resources, such as timber resources and fish stocks, and monetary values of ecosystem assets.

1.37 Finally, a longstanding ambition in environmental-economic accounting has been the derivation of adjusted measures of value added and wealth that take into account the cost of using up environmental assets. This ambition is considered in ecosystem accounting by measuring ecosystem degradation to reflect the loss of future flows of ecosystem services. This complements the measure of depletion defined in the SEEA Central Framework which focuses on the costs of using up stocks of natural resources. The range of connections among the accounts of the SEEA Central Framework and SEEA EA is described in more detail in Annex 1.2.

1.5.3 Connection to the System of National Accounts

1.38 In broad terms, the connection between SEEA EA and the SNA lies in the application and adaptation of the national accounting concepts and principles for the purpose of accounting for ecosystem assets and their services. A summary of the most relevant concepts and principles is provided in Chapter 2. The SEEA, encompassing the SEEA Central Framework and the SEEA EA, provides a system that complements the SNA by using the same accounting principles to integrate physical and monetary measures concerning the environment in a way that allows for comparison to the data from the national accounts.

1.39 The SEEA EA encompasses a broader asset boundary in physical terms than the SNA, reflecting the definition of environmental assets in the SEEA Central Framework wherein "*environmental assets are the naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity*" (SEEA Central Framework, para. 2.17). In addition, a key difference between the SEEA EA and the SNA lies in the measurement of ecosystem services. In the SNA, these flows are outside the production boundary that establishes the set of goods and services that are the focus of measures of output, value added and gross domestic product (GDP). The measurement of ecosystem services in both physical and monetary terms through ecosystem accounting thus provides measures that complement the estimates of output based on the SNA production boundary.

1.40 Further, the SEEA EA provides an approach to valuing the contribution of ecosystems consistent with SNA concepts and principles such that the monetary values can be used to provide complementary aggregates, such as of value added and wealth that take into account the supply and use of ecosystem services and are adjusted for ecosystem degradation and enhancement.

1.41 The derivation of complementary aggregates can be presented through a sequence of institutional sector accounts and balance sheets that build on the similarly labelled accounts in the SNA. Chapter 11 describes how these derivations can be undertaken. Two key aspects are that: (i) the degradation is allocated to the economic unit who suffers the loss of ecosystem services rather than to the economic unit who causes the degradation;[17] and (ii) a non-SNA quasi-sector labelled the "Ecosystem trustee" is introduced which holds stewardship over the ecosystem services that do not directly benefit an individual, private economic actor.

1.42 Other connections to the standard economic accounts can be developed including extended supply and use tables. In this case, there is particular interest in recording the use of ecosystem services by different economic units to better reflect the use of environmental assets as part of production and consumption patterns.

1.43 The SNA, as for all statistical methodology documents, is subject to revision on a periodic basis. Given the aim of ensuring alignment between the accounting principles and treatments in the SEEA and the SNA it will be necessary, from time to time, to revisit the treatments outlined in the SEEA EA. The need for maintaining alignment with the SNA is recognised in the SEEA EA research agenda.

1.5.4 Connections to other statistical methodology documents and guidance

1.44 SEEA EA incorporates the findings presented in a range of other technical materials on ecosystem accounting, as developed in the period from 2013 to 2020.[18] It also incorporates findings from the large number of projects and initiatives on ecosystem accounting. These materials, projects and initiatives, which were developed by different agencies in different contexts, were important in testing the framework described in the SEEA 2012 EEA. The testing evaluated technical and methodological options and assessed the relevance of a national accounting approach to ecosystem measurement for research, policy analysis and decision making. A range of these findings were collected and published in the Technical Recommendations.

1.45 In addition to research focused specifically on ecosystem accounting, there are a number of statistical methodology documents, handbooks and technical guidance that provide support for work on ecosystem accounting. These documents are of relevance both in the organisation of data for the compilation of ecosystem accounts and in the application of ecosystem accounting such as in thematic accounting and the derivation of indicators. The documents include:

---

[17] Alternative presentations which apply the polluter pays principle for the allocation of degradation are described in Chapter 12.

[18] These include Cropper & Khanna (2014); Maes et al. (2013); UNEP (2014); Weber (2014).

- SEEA methodological documents - SEEA Agriculture, Forestry and Fisheries (FAO & UNSD, 2020); SEEA-Energy (United Nations, 2018); and SEEA-Water (United Nations, 2012) - which provide guidance on accounting for stocks and flows for these themes.
- Framework for the Development of Environment Statistics (FDES) (United Nations, 2017) and its Basic Set of Environment Statistics (BSES) – which provide guidance on the collection and presentation of environmental statistics including a number of themes related to ecosystem accounting, including measures related to ecosystem condition.
- Global Statistical Geospatial Framework (GSGF) (UNSD, 2019) – which provides guidance on concepts and terminology for geospatial information from a statistical perspective.
- Measuring the Sustainability of Tourism (MST) (UNWTO, 2018) – which provides guidance on linking ecosystem accounting to measures of tourism activity.
- Ocean Accounts[19] – which provides a broad framework to connect relevant elements of the SNA, SEEA Central Framework and SEEA Ecosystem Accounting to harmonize priority data on the ocean covering economic, ecological, governance and social aspects.
- Exploring approaches for constructing species accounts in the context of SEEA EEA (UNEP-WCMC, 2016) – which provides guidance on how an accounting approach can be applied to compiling information about species of special concern, such as species of social, economic or conservation importance

1.5.5 Relationship to other global environmental measurement and assessment initiatives

1.46 With its broad coverage of all types of ecosystems, SEEA EA incorporates a wide range of ecological and biophysical data, including data on their extent and condition and flows of ecosystem services which commonly require data from biophysical models such as hydrological models. Given its intent to support comparable measurement in these areas over time and across countries, ecosystem accounting provides a robust framework and associated data that can be used to support measurement and reporting activity for a number of global environmental and sustainability initiatives. As well, in many cases, the data currently collected through these initiatives can provide source data for the compilation of ecosystem accounts.

1.47 Some key initiatives are listed below noting that there is a wide range of other programs of work at global, regional and national levels and within the corporate, academic and environmental NGO communities. All of these may be connected to work on ecosystem accounting and the SEEA more broadly.

- Monitoring of the Sustainable Development Goals (SDGs), in particular progress towards Goals 14 and 15;
- The Post-2020 Global Biodiversity Framework of the Convention on Biological Diversity (CBD) and its monitoring framework;

[19] See "Technical Guidance on Ocean Accounting for Sustainable Development" submitted as background document to the United Nations Statistical Commission, fifty-first session, 3-6 March 2020. Available at: https://unstats.un.org/unsd/statcom/51st-session/documents/BG-item-3h-TG_Ocean%20accounting_ESCAP-E.pdf

- The measurement of land degradation under the United Nations Convention to Combat Desertification (UNCCD);
- The measurement of greenhouse gas emissions and removals by the Land Use, Land Use Change and Forestry (LULUCF) under the United Nations Framework Convention on Climate Change (UNFCCC) and associated Nationally Determined Contributions (NDC);
- The regional and global assessments of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) including the IPBES values assessment;
- The development of wealth accounting encompassing measures of the value of natural capital (World Bank and UN Environment);
- International Union for the Conservation of Nature (IUCN) assessment frameworks including the Red List of Species, Red List of Ecosystems, and Key Biodiversity Area guidelines; and knowledge products such as the World Database on Protected Areas (UNEP-WCMC and IUCN);
- The Global Earth Observation (GEO) programs of work on biodiversity (GEO BON) including the listing of essential biodiversity variables (EBV) and essential ecosystem services variables (EESV), and the earth observation for ecosystem accounting (GEO EO4EA).

1.48 The relevant measurement and reporting frameworks across these initiatives are not currently aligned at the level of data items and definitions, although all have the common broad ambition to ensure that the environmental stocks and flows are a standard feature of decision making. There is consequently an opportunity for the statistical community to support improved alignment of data and indicators and to further enhance wider collaboration and engagement.

1.49 Given the range of environment related measurement and reporting work underway, there is also considerable potential for compilers of ecosystem accounts to consider how these data may be used or adapted for the purpose of compiling ecosystem accounts in their country. This rationale extends also to consideration of how data used in, for example, state of environment reports or environmental impact assessments, might be relevant sources of information for accounting.

1.6 Measurement, implementation and application

1.6.1 Introduction

1.50 The following discussion provides a summary of the roles of different agencies in implementation and alternative compilation pathways that might be adopted. The implementation of ecosystem accounting will also require ongoing engagement with users to ensure the accounts are fit for purpose. Users of the accounts will include public policymakers and analysts, ecosystem and natural resource managers, private sector businesses, local communities and other stakeholders.

1.6.2 The role of national statistical offices and other agencies

1.51 NSOs have traditionally focused on producing official statistics independently, often in relative isolation from other data producers. However, the role of NSOs has begun to change over the past several years, as new technologies have allowed for unparalleled levels of data collection from a variety of new sources, and as official statistics have become one source of information among many. Increasingly, this has prompted NSOs to undertake the role of data stewards. As data stewards, NSOs have shifted from being solely producers of statistics, to also becoming service providers, whereby NSOs facilitate a collaborative approach to data and statistics across different data and statistics communities and provide oversight and governance.

1.52 Arguably, no other statistical domain demonstrates the potential role of NSOs as data stewards more than the ecosystem accounting. The implementation of the SEEA EA is often led by the official statistics community and NSOs, but given the highly cross-cutting and spatial nature of ecosystem accounting, implementation necessitates a highly collaborative approach. Implementation will require the active participation of representatives of many different agencies and disciplines, including geography, ecology, economics and statistics. It will also include, in many countries, the need to co-ordinate with agencies and experts at sub-national administrative levels. A key objective is to work towards the appropriate institutionalization of the processes (including data sharing), roles and responsibilities for the compilation of ecosystem accounts.

1.53 Of particular note in the collaboration on ecosystem accounting is the role of environmental policy agencies and associated technical research agencies concerning for example, geographical and remote sensing data, climate and water resources, biodiversity and environmental monitoring. Together with the associated networks of scientists and researchers, these agencies will often play a critical role in collecting and validating local environmental data and knowledge. Since NSOs traditionally have less experience with these types of environmental data, collaboration with these agencies in the development of ecosystem accounts would be expected.

1.54 NSOs, in collaboration with relevant agencies, should provide oversight and governance by providing an independent and expert opinion of data to ensure trust and quality. Given the wide interest in ecosystem accounting by multiple stakeholder groups (e.g., academia, government, private sector, etc), the role of NSOs in promoting high-quality ecosystem accounts is especially important. Moreover, the voice of NSOs can be an authoritative one by virtue of their independence and particularly unique role within government.

1.55 The SEEA website[20] provides a range of material to support implementation including general advice on establishing programmes of work, compilation guidance documents and a knowledge containing examples of SEEA work. In addition, the *Guidelines on Biophysical Modelling for Ecosystem Accounting* (UNSD, n.d.-a, forthcoming) and the *Guidelines on the Valuation of Ecosystem Services and Ecosystem Assets* (UNSD, n.d.-b, forthcoming) provide advice specific to implementation of ecosystem accounts. Ecosystem accounts compilers are also encouraged to learn from the experiences in other countries and regions.[21]

1.6.3 Ecosystem accounting compilation approaches

1.56 Ecosystem accounts are most informative when not conducted as one-off, irregular or short term studies of specific areas or environmental themes. Generally, the data generated from such studies do not support ongoing, long-term measurement of trends and hence the design and monitoring of policy responses. Aligned with the expectations associated with the preparation of common socio-economic data, including national accounts, employment,

[20] https://seea.un.org/

[21] Many examples of ecosystem accounting can be found in the SEEA Knowledge Base at: https://seea.un.org/content/knowledge-base

population census, it is expected that, progressively, long time series of ecosystem accounting data can be established. This will provide the opportunity to strengthen and improve institutional arrangements and measurement approaches over time and will contribute to the compilation of enduring data sets. In turn, these data sets can underpin further research and analysis, which, ideally, would generate a virtuous circle of improved data supply.

1.57 Compilation of the ecosystem accounts can follow several alternative approaches located along a spectrum. At one end are "spatially-explicit" approaches which entail detailed and comprehensive spatial measurement of ecosystem services and rigorous delineation of ecosystem assets. At the other end are "minimum spatial" approaches which seek to provide a broad overview of trends in key ecosystem types and services. The content of the accounts compiled using either of these extremes will be conceptually aligned but there will be differences in the level of detail shown in the accounts (e.g., concerning the number of ecosystem types) and, in the minimum spatial approach, there will be limited capacity to disseminate outputs as maps (and other spatially referenced outputs) showing the location and configuration of ecosystem assets and the services they supply.

1.58 In practice, the compilation of ecosystem accounts will lie between these two extremes with the implementation approach being dependent on (i) the policy focus; (ii) the availability of source data; and (iii) the resources available for compilation. In general terms, increasing the level of spatial detail has the potential to increase the level of robustness of the accounts, and perhaps open up a wider range of applications, but it will also generally increase the level of complexity in compilation. In practice, it is likely that the spatial resolution of the accounts will increase over time as more and better data become available and as methods and technologies improve.

1.59 A common starting point for ecosystem accounting will be the compilation of ecosystem extent accounts which provide a statistical frame for the accounts. Where national level data are not available, global data sets can provide a suitable starting point. Beyond the extent account, depending on the data available and issues of particular interest, efforts may turn to the compilation of ecosystem condition accounts for different ecosystem types and to the quantification of ecosystem services flows. Monetary valuation, which commonly relies on the organisation of a wide array of data in physical terms, could be undertaken as a final part of a compilation process but it is not a mandatory component.

1.6.4 Uses and applications of ecosystem accounting

1.60 In support of ongoing reporting requirements and discussion of emerging issues, the accounts provide information that is:

- comprehensive, i.e., it encompasses accounting for all ecosystem types across the terrestrial, freshwater, marine and subterranean realms and for a wide range of ecosystem services;
- structured, i.e., it follows an internationally agreed accounting framework encompassing agreed rules aligned with those of the SNA;
- consistent, i.e., it presents data that are consistent over time and with respect to concepts and classifications;
- coherent, i.e., it integrates a broad range of data sets in order to provide information on ecosystem services and assets;
- spatially referenced, i.e., it links data to the scale of ecosystems and allows the integration of data across different accounts; and

- adaptable, i.e., it allows for the use of targeted measurement scopes, e.g., with respect to ecosystem services and ecosystem types, to suit the context and for the measurement scope to be increased over time.

1.61 As well, because these features are contained within an international statistical methodology document, the resulting data have the potential to encourage increased use of common classifications and definitions. This should assist in: reducing costs associated with discovering and using data; increasing the potential to develop shared technologies and data management solutions; and raising the possibilities to share methods and undertake collaborative research.

1.62 Given these features, ecosystem accounts provide a range of information in support of economic and environmental policy and decision-making. These applications include: highlighting the ecosystems and ecosystem services of particular concern to policymakers; providing information to support the design of policy responses and instruments; assisting the ongoing management of ecosystems; monitoring the effectiveness of various policies through indicators of performance; providing detailed spatial information on ecosystem services supply; supporting assessments of biodiversity; and mainstreaming environmental data in economic and financial decision-making.

1.63 The SEEA EA is primarily intended to support national level policy decision making with a focus on connecting information about multiple ecosystem types and multiple ecosystem services to macro-level economic information (e.g., measures of national income, output, value added, consumption and wealth). At the same time, the theory and practice of ecosystem accounting is applicable at subnational scales. For example, ecosystem accounts can be used to support decision making for individual administrative areas such as provinces and urban areas, and for environmentally defined areas such as water catchments, protected areas, biodiversity priority areas and coastal zones.

1.64 Since the compilation of ecosystem accounts often involves the use of spatially explicit data, a richer understanding of national level information can be portrayed through the analysis of differences across locations and regions within a country. Also, the use of spatially explicit data within the ecosystem accounting framework can support the co-ordination of policy from local to national scales by establishing a common and agreed set of data and a common framing of the relationship between the environment and economic and human activity.

1.65 In using a harmonising approach and in applying a set of coherent data the accounts can, in turn, support consistent application of a wide variety of specific approaches including cost-benefit analysis, risk assessments, system-based modelling, scenario analysis and forecasting and trade-off analysis. The availability of coherent data will also support the incorporation of environmental data into the decision making of business and finance sectors complementing the wide range of initiatives underway in those sectors to recognise the importance of ecosystems and biodiversity. [22] Thus, data from ecosystem accounts can be used in conjunction with other methods and tools for application in policy and decision making. [23]

1.66 Ideally, accounts should be updated on a regular basis (e.g., annually) considering source data availability and user needs, so as to ensure that a structured, comprehensive and up-to-date database is available to respond quickly to policy demands for specific information. Although

[22] Such initiatives include the work of the Capitals Coalition, Global Reporting Initiative (GRI), International Integrated Reporting Council (IIRC), Sustainability Accounting Standards Board (SASB), World Business Council for Sustainable Development (WBCSD) among many others.

[23] For a summary of potential applications see reports of the Policy Forum on Natural Capital Accounting for Better Decision Making (https://www.wavespartnership.org/en/policy-forum-natural-capital-accounting-better-decision-making) and the UNSD SEEA policy guides (https://seea.un.org/content/enhanca-enhance-natural-capital-accounting-policy-uptake-and-relevance).

assessment of specific policies or investments will likely require information additional to that presented in the ecosystem accounts, the data from the accounts should be able to describe relevant structures and trends, and in many cases, will support the modelling of a wide range of environmental and economic impacts. Further, where different assessments are based on a common underlying data set, there can be improved comparison of policy alternatives.

1.67 Notwithstanding the many potential applications, ecosystem accounts do not provide an exhaustive coverage of all relevant environmental data. In the first instance, data from the SEEA EA complement the data collated using the SEEA Central Framework which, as described in Annex 1.2, contains a wide variety of other data on the links between the environment and the economy such as concerning flows of pollutants and residuals and measures on expenditure on environmental protection and restoration. Second, particularly in initial stages of implementation, it is likely that the coverage of ecosystem accounts will not be complete – for example, they may be focused on specific sub-national areas or a limited set of ecosystem services. Finally, in the context of monetary valuation, as outlined in section 1.2, the SEEA EA does not include all potential economic values, in particular consumer surplus and non-use values. Thus, depending on the user requirements, additional measurement and analysis will be required.

1.7 Structure of the SEEA EA

1.68 The SEEA EA comprises five sections A to E. Sections A to C comprise the international statistical standard describing the accounting framework and the physical accounts. Section D describes internationally recognised statistical principles and recommendations for the monetary valuation of ecosystem services and assets. Section E describes applications and extensions of ecosystem accounting.[24]

1.69 Section A provides the introduction (Chapter 1) and the overview of the ecosystem accounting framework and associated principles (Chapter 2). Collectively, these chapters describe the background and rationale for ecosystem accounting and place this work within the broader context of work on the measurement of the relationship between the environment and the economy. The various parts of the ecosystem accounting framework introduced in Chapter 2 are described in greater detail in later chapters.

1.70 Section B covers accounting for ecosystem extent and condition. Chapter 3 describes the definition and delineation of spatial units for ecosystem accounting. These units, termed ecosystem assets, are the building blocks for the accounting framework and provide the structure for the organisation of data about ecosystems. Chapter 3 also presents a reference classification for ecosystem types, the IUCN Global Ecosystem Typology (IUCN GET). Chapter 4 outlines the way in which data about the size of ecosystem assets, usually in terms of their area, can be organised and presented in an ecosystem extent account. Chapter 5 presents a three-stage approach to accounting for ecosystem condition, where ecosystem condition is measured in relation to the integrity of the ecosystem assets. Data on ecosystem characteristics are structured using the SEEA Ecosystem Condition Typology and are referenced to a condition appropriate for the ecosystem type.

1.71 Section C presents accounting for ecosystem services in physical terms. Chapter 6 focuses on a wide range of conceptual issues including the link between ecosystem services and benefits, the definition of final and intermediate services, the accounting treatments for selected ecosystem services and other flows, and the definition of ecosystem capacity. The chapter

[24] United Nations Statistical Commission, Report on the fifty-second session, E/2021/24, decision 8g, https://unstats.un.org/unsd/statcom/52nd-session/documents/2021-30-FinalReport-E.pdf.

also presents the SEEA Ecosystem Service Reference List that provides descriptions for 30 ecosystem services. Chapter 7 outlines the accounting entries for the ecosystem services flow account in physical terms using supply and use tables and discusses some specific measurement issues, such as the definition of measurement baselines for the quantification of ecosystem services flows for accounting purposes.

1.72 Section D concerns the monetary valuation of ecosystem services and ecosystem assets. Chapter 8 describes the principles of monetary valuation for accounting purposes, highlighting the application of the exchange value concept as described in the SNA. Chapter 9 outlines the accounting entries for the ecosystem services flow account in monetary terms, building on the same account in physical terms, and summarises the appropriate valuation techniques for estimating flows of ecosystem services in monetary terms for accounting purposes. Chapter 10 describes the monetary ecosystem asset account. This account incorporates entries for the opening and closing value of ecosystem assets and for their degradation, enhancement and other changes in value. Chapter 10 also describes the net present value approach to the valuation of ecosystem assets. Chapter 11 demonstrates how the monetary values from the ecosystem services flow account in monetary terms and the monetary ecosystem asset account can be combined with standard accounts from the SNA to provide extended economic accounts, including extended supply and use tables, extended balance sheets and extended sequence of institutional sector accounts.

1.73 Section E introduces a range of applications and extensions of the ecosystem accounts. Chapter 12 considers complementary approaches to valuation, recognising the range of ways in which ecosystems and related flows may be valued in monetary terms and placing ecosystem accounting values in context. Chapter 13 describes accounting for specific environmental themes, also known as thematic accounting. Four themes are introduced in this chapter namely, biodiversity, climate change, oceans and urban areas. Chapter 14 summarises the links between ecosystem accounts, indicators and indicator frameworks including those related to the monitoring of global agreements such as the Convention on Biological Diversity and the 2030 Agenda for Sustainable Development.

1.74 A number of chapters contain annexes that present classifications, examples and other materials to support explanation of concepts and compilation of accounts. Annexes to the whole document include a research agenda, a glossary of key terms, a stylized example and a list of references.

Annex 1.1: Main conceptual changes from the SEEA 2012 EEA

A1.1 The SEEA 2012 EEA presented initial efforts to define a measurement framework for integrating biophysical data, tracking changes in ecosystems and linking those changes to economic and other human activity. Its endorsement at the forty-fourth session of the United Nations Statistical Commission in 2013 was recognised as an important step forward in the development of a statistical framework for ecosystem accounting. The definitions and accounting treatments presented in the SEEA EA build on the measurement framework described in the SEEA 2012 EEA.

A1.2 Research and testing of the concepts, definitions, classifications and treatments outlined in the SEEA 2012 EEA has seen substantial refinement and clarification of the ecosystem accounting framework. The key areas of progress are noted in this section. Beyond technical advances, the endorsement of the SEEA 2012 EEA led to a substantial increase in the awareness of, and involvement in, ecosystem accounting across many countries, disciplines and sectors. This broad engagement, particularly the engagement beyond the community of official statisticians, added considerable richness to the economic, ecological, geographical, accounting and statistical basis for ecosystem accounting.

A1.3 In relation to spatial units there has been a steady refinement in the choice of labels and description of types of spatial units. In the SEEA 2012 EEA the subject was framed in terms of a hierarchy of basic spatial units (BSU), land cover/ecosystem functional units (LCEU) and ecosystem accounting units (EAU). In the SEEA EA, LCEU have been relabelled ecosystem assets (EA) and are regarded as the key conceptual unit. EAU have been relabelled ecosystem accounting areas (EAA) but are conceptually unchanged in their role within ecosystem accounting. BSU have been retained in the SEEA EA but are now regarded as a means to implement the accounting approach rather than being conceptually nested spatial units.

A1.4 The SEEA EA provides an agreed classification of ecosystem types based on the IUCN GET. This is a significant advance beyond the broad classes of LCEU provided in the SEEA 2012 EEA. Principles for the delineation of ecosystem assets by ecosystem type are now described to support consistent application of data from various sources in the task of delineating spatial units for ecosystem accounting. Using these principles, a more coherent description of accounting for ecosystem extent has been described.

A1.5 The SEEA 2012 EEA provided a basic description of accounting for ecosystem condition using a reference condition approach. The SEEA EA has retained the use of a reference condition-based approach but considerably expands description of the measurement approach. In particular, the SEEA EA determines the focus of measurement to be ecosystem integrity, details the SEEA ecosystem condition typology for the organisation of characteristics, variables and indicators of condition, and outlines a three-stage approach to accounting for ecosystem condition involving the selection of variables, the referencing of indicators and aggregation to provide ecosystem condition indices. There is now also a description of the application of the approach in natural and anthropogenic ecosystems, links to the assessment of biodiversity and to the use of indicators of environmental pressures.

A1.6 The definition of ecosystem services in the SEEA EA remains the same as in the SEEA 2012 EEA and, in broad terms, the conceptual intent in the measurement of ecosystem services has not been changed. However, there are substantive improvements in the discussion of the links to benefits and well-being, in the description of the boundary with abiotic flows and in the definition of intermediate services which were not explicitly defined in the SEEA 2012 EEA. In addition, while a classification of ecosystem services has not been established, a comprehensive reference list of ecosystem services has been developed in consultation with the custodians of the leading international ecosystem service classifications and typologies. There is also a significant refinement in the description of accounting treatments for a number of ecosystem services including biomass provisioning services, global climate regulation services and services related to water supply. These treatments have flowed through to the description of a complete supply and use table for ecosystem services in physical terms that had only been introduced in general terms in the SEEA 2012 EEA.

A1.7 The SEEA 2012 EEA introduced the concept of ecosystem capacity without providing a singular definition. The SEEA EA provides a definition of ecosystem capacity and describes associated concepts such as potential supply and ecosystem capability. It does not however, provide an account for ecosystem capacity.

A1.8 As in the SEEA 2012 EEA, the SEEA EA recognises the challenges involved in monetary valuation of ecosystem services and ecosystem assets. The use of the exchange value concept has been retained and an improved description has been provided on the link to alternative valuation concepts such as welfare values. A focus has been placed on determining which valuation techniques can be applied to measure exchange values and a preference order has been established concerning the application of valuation techniques for this purpose. The use of the net present value technique to value ecosystem assets in monetary terms has been retained but discussion of its application in an ecosystem accounting context has been considerably expanded. Further, definitions for a range of entries in the monetary ecosystem asset account, including ecosystem degradation and enhancement have been developed.

A1.9 The potential for extended monetary accounts in which data from the ecosystem accounts are combined with the standard SNA accounts has been clarified. SEEA 2012 EEA identified two potential models for presenting extended institutional sector accounts. Research for the SEEA EA identified a third alternative involving an ecosystem trustee and this has been agreed to be an appropriate presentation for the sequence of accounts as described in Chapter 11.

A1.10 The SEEA 2012 EEA did not provide material beyond the description of the ecosystem accounts and links to the sector accounts of the SNA aside from an introduction to accounting for biodiversity and accounting for stocks of carbon. In the SEEA EA, three chapters have been included to describe a wide range of applications and extensions of ecosystem accounting including complementary approaches to valuation, indicators and thematic accounting. Accounting for biodiversity and accounting for stocks of carbon has been incorporated within the discussion of thematic accounting.

Annex 1.2: Linking the SEEA EA and the SEEA Central Framework

Introduction

A1.11 The SEEA EA is designed to complement the SEEA Central Framework and hence provide a complete framework for describing the relationship between the environment and the economy using the same accounting principles. The complementarity can be considered in two ways – first with respect to the definition of environmental assets and second with respect to the coverage of data within a basic driving force-pressure-state-impact-response (DPSIR) framework (European Environment Agency, 1999).

A1.12 With regard to environmental assets, the SEEA Central Framework provides a definition of environmental assets that encompasses the measurement of both individual environmental assets (such as land, soil, water and timber) and ecosystem assets. The associated asset boundary is broader than that provided for in the SNA by establishing a physical boundary for assets and not requiring flows of benefits to accrue to owners of environmental assets. This extension is applied in both the SEEA EA and the SEEA Central Framework.

A1.13 Within this broader asset boundary, the focus of accounting in the SEEA Central Framework is on the individual resources that make up the environment, such as minerals, timber, water, land and soil. This focus comprises those types of individual resources used in economic activity. The focus of accounting for environmental assets in the SEEA EA is on ecosystems and, in many senses, how individual components function together. Consequently, there are often strong connections between accounting for individual environmental assets, as described in the SEEA Central Framework, and measures of ecosystem assets and ecosystem services, for example for timber resources, forest ecosystems and wood provisioning services.

A1.14 With its focus on individual resources, the accounting of the SEEA Central Framework considers only the benefits accruing from the use of those resources in production as defined by the SNA production boundary. Thus, the monetary value of the resources is linked to the values of minerals, energy, timber, fish and other resources extracted or harvested from the environment. In the SEEA EA, the set of benefits within scope is broadened to include a wide range of ecosystem services. This covers both contributions to SNA production and other services such as air filtration, water regulation, and recreation-related services.

A1.15 A common framing for measurement and analysis of the connection between the environment and the economy is the DPSIR framework. The focus of the SEEA EA is on the state and impact components of this framework. Thus, measures of the changing mix of ecosystem types, the changes in condition of ecosystem assets and the changes in ecosystem services provide a more complete picture of environmental *state* and the *impacts* of economic and human activity than provided by the accounts of the SEEA Central Framework.

A1.16 The SEEA Central Framework on the other hand provides a rich framework for considering the *pressures* exerted on the environment and ecosystems through economic activity, in particular through its measurement of physical flows (e.g., concerning water use, energy use, air emissions, solid waste) but also through the data on the stocks and use of natural resources. The SEEA Central Framework also supports the organization of data on the *responses* to environmental issues through accounts concerning environmental taxes and subsidies, environmental protection expenditure and the activities of the environmental goods and services sector (EGSS).

A1.17 While there is the potential to identify common points of measurement, a general difference is that the focus of accounting in the SEEA Central Framework is at the national level whereas in ecosystem accounting there is commonly also a focus on sub-national levels and often measurement involves use of detailed spatial data and models. Thus, the integration of data from the SEEA Central Framework, for example on pressures arising from residual flows, may require the spatial disaggregation of data on residual flows to locations within a country, such that the link between the residual flows and changes in ecosystem condition can be clearly established. A broad, national-level, comparison of residual flows and condition at a national level is likely to miss important variations across locations within a country.

A1.18 In the area of monetary valuation, both the SEEA EA and the SEEA Central Framework apply the exchange value concept and use the net present value approach for the valuation of environmental assets. The primary difference between estimates of the monetary value of environmental assets therefore concerns the range of flows that are within scope of valuation. As noted above, for the SEEA Central Framework this is limited to those flows within scope of the SNA, primarily concerning extraction/harvest of natural resources. For ecosystem accounting the scope extends to capture all relevant ecosystem services. This extension to include a broad range of ecosystem services leads to an expanded scope of wealth in the SEEA EA since the underlying environmental assets are recognised to provide a wider set of benefits.

A1.19 The following sections provide additional details on these connections. Neither the SEEA Central Framework nor the SEEA EA provide a complete set of information for analysing the environmental-economic relationship but, when combined, a rich and coherent data set can be envisaged.

Recording environmental assets and related stocks

A1.20 As noted above, the SEEA Central Framework has a focus on individual assets, i.e., without considering the broader context or system in which those assets, commonly natural resources, are located. For example, the SEEA Central Framework has a focus on timber resources, whereas SEEA EA has a focus on the forest. The forest will not only supply wood biomass but also a range of other ecosystem services. The same comparison can be drawn between fish resources and marine or freshwater ecosystems.

A1.21 From the perspective of recording physical changes in the stock of ecosystem assets there should be a coherence with related recordings of changes in individual environmental assets. That is, for the same accounting period and in the same location, the changes in stock of natural resources and changes in ecosystem assets should be the same. For example, a change in ecosystem type from forest to cultivated land as recorded in the ecosystem accounts should also be reflected in a reduction in timber resources as measured in the timber resource asset account.

A1.22 A particular connection that can be highlighted concerns the link between data on ecosystem extent and data on land cover and land use. For terrestrial areas there should be a reasonable concordance between data on land cover and ecosystem extent since land cover is a key variable in delineating ecosystem types. Further, for cultivated areas, data on land use may be considered in delineating ecosystem types.

A1.23 As a result of the coherence in the measurement of physical stocks, there are important advantages for ecosystem accounting in compilation since it becomes possible to use the range of materials and documentation that has been developed related to the measurement of water resources, including SEEA-Water (United Nations, 2012); and for agriculture, forestry and fisheries in the SEEA for Agriculture, Forestry and Fisheries (SEEA-AFF) (FAO & UNSD, 2020). While these materials have generally not been developed for ecosystem accounting purposes, they will support the development of relevant estimates and accounts, especially in relation to methods and data sources.

A1.24 In addition, SEEA EA describes two areas, accounting for carbon and accounting for species populations, to which the asset accounting approaches based on measuring stocks and changes in stocks as described in the SEEA Central Framework are applied. The emerging range of materials in these two areas of measurement can also be used to support the measurement of ecosystem assets and ecosystem services and should be coherent with the individual environmental asset accounts of the SEEA Central Framework.

A1.25 The SEEA Central Framework also defines the depletion of natural resources and introduces the concept of ecosystem degradation. The distinction between these concepts lies primarily in the scope of the measurement and mirrors the distinction between a focus on individual environmental assets and a focus on ecosystem assets. Thus, depletion is defined in relation to using up the stock of resources relative to the rates of regeneration; while degradation is defined in relation to changes in condition and future flows of ecosystem services.

A1.26 Since depletion is measured with respect to an individual resource with a single benefit stream, there is a direct connection that can be made between changes in the stock and changes in future benefit streams. With degradation, this relationship is more complex since a bundle of ecosystem services will generally be supplied by a single ecosystem asset and the relationships between each service and changes in ecosystem condition will vary. Nonetheless, for a given ecosystem asset, there should be a reasonably close relationship between measures of depletion and measurement of degradation as they pertain to provisioning services such as wood or fish biomass.

Environmental flows

A1.27 The SEEA Central Framework describes accounting for environmental flows, such as of water, energy, GHG emissions and solid waste. These flows are recorded in physical terms. Three types of flows are defined – natural inputs, products and residuals.

A1.28 *"Natural inputs are all physical inputs that are moved from their location in the environment as part of economic production processes or are directly used in production"* (SEEA Central Framework, para. 3.45). In general terms, this definition will encompass the set of provisioning services that contribute to the production of agricultural, forestry, fisheries and similar outputs. However, a number of differences in scope must be noted:

- Natural inputs include inputs of mineral and energy resources, inputs from soil resources (excavated), and energy inputs from renewable sources (e.g., solar, wind). These are excluded from the scope of ecosystem services but may be recorded as abiotic flows in the SEEA EA framework.
- Natural inputs include inputs of timber, aquatic (e.g., fish) and other biological resources only in cases where the production process is uncultivated or unmanaged, since cultivated biological resources are produced within the economy. In SEEA EA, provisioning services are recorded in both cultivated and uncultivated contexts.
- Natural inputs include inputs of water resources. In the SEEA EA following the treatment in Chapter 6, these flows may be recorded as a proxy for the ecosystem services underpinning the supply of water such as water regulation and water purification but otherwise should be recorded as abiotic flows.
- Natural inputs include inputs of nutrients, carbon, nitrogen and other elements. These flows are not commonly recorded in an ecosystem accounting context but may be relevant in the measurement of some regulating and maintenance services, for example in the context of recording global climate regulation services and water purification services.

- Natural resource residuals defined in the SEEA Central Framework represent those flows of natural resources that are extracted or harvested but are immediately returned to the environment. Examples include discarded catch in fishing and felling residues in forestry. In SEEA EA, flows of provisioning services are recorded in gross terms before natural resources residuals are recorded thus the recording is aligned with the gross recording of natural inputs used in the SEEA Central Framework.

A1.29 Physical flows of products take place within the economy and are not recorded within the SEEA EA. Nonetheless, in concept, flows of final ecosystem services that contribute to SNA benefits should be able to be linked to physical flows of products, for example, biomass provisioning services can be linked to flows of food and other products to which they are inputs. This may be of particular interest in developing "footprints" and understanding the extent to which ecosystem services are embodied in traded goods and services.

A1.30 *"Residuals are flows of solid, liquid and gaseous materials, and energy that are discarded, discharged or emitted by establishments and households through processes of production, consumption or accumulation"* (SEEA Central Framework, para. 3.73). These physical flows are generally not recorded directly in the ecosystem accounts. Rather, these flows reflect either measures of environmental pressures that may be used as proxy measures in the assessment of ecosystem condition; or measures related to the flow of ecosystem services provided by ecosystem assets that receive, store or process the relevant residual (e.g., particulate matter (PM2.5) absorbed by trees will be a component in the measurement of air filtration services).

A1.31 While there is not a direct alignment in the recording of residual flows between SEEA EA and the SEEA Central Framework, the quantities of residual substances that are not broken down or absorbed will be of particular interest. Indeed, since flows of residuals are likely to affect the capacity of ecosystem assets to supply ecosystem services, the potential to quantify this type of feedback loop is an important aspect in considering the links between ecosystem accounting and the accounts of the SEEA Central Framework. Information on residuals flows will also be relevant in the assessment and valuation of ecosystem disservices and externalities. This is discussed in Chapter 12.

A1.32 In terms of accounting structures, the basic structure of the ecosystem services flow accounts is derived from the design of physical supply and use tables (PSUT) from the SEEA Central Framework. There are three main alterations. First, unlike the PSUT, which contains just one column representing the environment as a whole, the ecosystem services flow accounts contain multiple columns, each representing a different ecosystem type.

A1.33 Second, the PSUT covers three types of flows: natural inputs, products and residuals. While in general, the concept of ecosystem services links to natural inputs as defined in the Central Framework, the coverage of natural inputs is limited to provisioning services (as discussed above), and flows of regulating and maintenance services and cultural services are not included in the SEEA Central Framework.

A1.34 Third, the SEEA Central Framework does not consider the ways in which different stocks and flows may be connected spatially (i.e., it incorporates an individual resource perspective) and it describes accounting at national scale rather than allowing for the location of ecosystems and their services to be reflected in the accounts. In contrast, the ecosystem services flow account has the capacity to record intermediate services reflecting the dependencies among ecosystem assets and there is the potential to present the results in the form of maps.

Environmental transactions

A1.35 Chapter 4 of the SEEA Central Framework focuses on the recording of environmental transactions including environmental activity accounts, environmental taxes, subsidies and other payments related to the environment. Information on environmental activities, particularly those related to the restoration of ecosystems, may be of particular relevance in both the compilation of ecosystem accounts and in providing a more comprehensive description of policy responses, for example to changes in ecosystem condition. Measures of expenditure on, for example, ecosystem restoration, may be compared to changes in ecosystem condition and changes in flows of ecosystem services to support the assessment of the effectiveness of any expenditure.

A1.36 The Classification of Environmental Activities has four classes that will be of most relevance: Class 1 – Environmental protection of ambient air and climate; Class 6 – Environmental protection of biodiversity and landscapes; Class 13 – Resource management of other biological resources (excluding timber and aquatic resources) and Class 14 – Resource management of water resources.

A1.37 Concerning environmental taxes, subsidies and other payments related to the environment, there will commonly be a direct connection that can be made between a specific activity that affects ecosystems and the services they provide. For example, taxes may be imposed to reduce pollution that would otherwise reduce the condition of river systems and payments may be made to ecosystem managers for conserving certain areas of land or maintaining the population of certain species (e.g., pollinator species). In this context, the data on taxes and subsidies from the SEEA Central Framework, when available at a sufficient level of granularity, can be compared to the ecosystem changes recorded in the ecosystem accounts to support assessment of the effectiveness of policy instruments.

2 Principles of ecosystem accounting

2.1 Introduction

2.1 This chapter provides a summary of the ecosystem accounting framework, its core conceptual components, the main accounts and relevant national accounting principles. It demonstrates the nature of the connections between the different accounts and explains the integration of ecological and economic approaches to describing the relationship between the environment and the economy.

2.2 Overview of the ecosystem accounting framework

2.2.1 An accounting approach

2.2 The essence of an accounting approach lies in recording data on relevant stocks and flows in a systematic way. In corporate accounting, the focus of accounting is business units and in national accounting the focus is on the range of different economic units[25] (businesses, households, governments) located in a geographical area, usually a country. Accounting can also be undertaken for an individual asset such as a house.

2.3 Ecosystems are the focus of ecosystem accounting. Ecosystem accounting thus aims to record data in a systematic fashion on the stocks and flows of selected ecosystems. While ecosystems are the starting focus, the accounting approach applied in the SEEA also encompasses documenting the relationships among ecosystems, people and economic units. In doing so, it provides a basis for analyzing the role that ecosystems play in supporting economic and other human activity and understanding the impact that economic and human activity has on ecosystems.

2.4 A feature of ecosystems is that they can be attributed to specific locations. Indeed, the measurement of ecosystems is most commonly undertaken with an understanding of where different ecosystems are located, how they are arranged in relation to other ecosystems and how they are changing over time. Ecosystem accounting therefore places considerable focus on recording data on the stocks and flows in a spatially-explicit way.

2.5 The approach described in the SEEA EA has two particular features. First, it describes accounting concepts and structures in both physical and monetary terms. Second, it applies the accounting principles from the national accounts described in the 2008 SNA. This facilitates comparison of data from ecosystem accounts with the data from the conventional economic accounts, for example, measures of GDP.

2.2.2 Measurement perspectives on ecosystems

2.6 Following the Convention on Biological Diversity (CBD) an ***ecosystem is a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit***.[26] Ecosystems change as a result of natural processes (e.g., succession and natural disturbances, such as a storm), wider environmental dynamics such as climate change, and because of direct human actions involving deliberate management or

[25] Referred to in the SNA as institutional units.

[26] See CBD, article 2, entitled "Use of terms" https://www.cbd.int/convention/articles/?a=cbd-02

disturbance, such as the conversion of ecosystems to other uses, extraction of natural resources, and restoration and conservation activity.

2.7 While ecosystems are the clear focus for accounting, the functional ecological unit that is an ecosystem can be viewed in a number of different ways that are all relevant in different measurement contexts and for different purposes. The statistical framework of the SEEA EA integrates these various perspectives. Five distinct measurement perspectives are relevant:

- Spatial perspective: Here the concept of an ecosystem is used to establish the number of occurrences of ecosystems within a defined territory that can be classified in mutually exclusive ways. In doing so, a comprehensive measurement base of statistical units is formed.
- Ecological perspective: Here the concept of an ecosystem is the focus for the measurement of its integrity, health and condition and serves to underpin concepts such as ecosystem resilience and the assessment of ecological thresholds.
- Societal benefit perspective: Here ecosystems are seen as a source of benefits for people, the economy and society potentially in terms of a relational connection or in a more economic sense of supplying services and benefits.
- Asset value perspective: Here ecosystems are seen as assets that provide services and benefits into the future depending on their ecological status and the social demands for ecosystem services. Issues of ecosystem degradation and enhancement are considered in this perspective.
- Institutional ownership perspective: Here there is a consideration of ecosystems in relation to existing economic and legal entities. Issues of stewardship and allocation of degradation costs are considered here.

2.8 Each of these perspectives will have different measurement considerations but they are fundamentally interconnected since they all have the same underlying focus for measurement, i.e., the ecosystem.

2.9 Under each of these perspectives, various labels are used which refer to specific understandings or interpretations of the ecosystem being measured. To avoid the confusion of having different labels for different perspectives within the ecosystem accounting framework, and to support the integration of perspectives, the label **ecosystem asset** is applied in the SEEA EA. Thus, the label ecosystem asset is used to refer to the individual spatially-defined statistical units that comprise the set of ecosystems that determine the scope of the accounts (spatial perspective); to the ecological functional units that are the focus of biophysical measurement and assessment (the ecological perspective); the supply or producing units that deliver ecosystem services and associated benefits (the societal benefit perspective); the assets which are stores of future value (the asset value perspective) and the entities that have status in their own right or may be linked to existing legal, social and institutional units (the institutional ownership perspective).

2.10 A unique feature of ecosystem accounting is its use of the same statistical unit across all accounts, building on the measurement base established through the spatial perspective. This may represent a measurement compromise for any single perspective, but it has the significant advantage of facilitating the co-ordination and integration of data in a manner that supports informed discussion across the perspectives.

2.11 Since it is the spatial perspective that supports linking the components of the accounting framework, and the definition of ecosystem assets speaks directly to this perspective. Thus, ***ecosystem assets are contiguous spaces of a specific ecosystem type characterized by a distinct set of biotic and abiotic components and their interactions.*** This definition is a statistical representation of the scientific concept of an ecosystem described in the CBD definition. The definition is thus not bound to other measurement perspectives and should not be regarded as being linked specifically to an ecological, economic or institutional interpretation of ecosystems. Defined in this way, ecosystem assets remain nested within the broader concept of environmental assets as defined within the SEEA Central Framework which itself based on the components of the biophysical environment and not to considerations such as ecological status, benefit flows, or ownership.

2.2.3 The logic of the ecosystem accounting framework

2.12 The central logic of the ecosystem accounting framework builds from the definition of an ecosystem asset. A set of ecosystem accounts will encompass those ecosystem assets within a defined ecosystem accounting area. The ***ecosystem accounting area (EAA) is the geographical territory for which an ecosystem account is compiled***. An EAA may be defined by, for example, the boundary of a country, a sub-national administrative area, a water catchment or a protected area. Within an EAA, the ecosystem assets will reflect different ecosystem types each with their own structure, function and composition and with associated ecological processes.

2.13 Information on the ecosystem types will be reflected in measures of ecosystem extent and ecosystem condition. ***Ecosystem extent is the size of an ecosystem asset.*** It is most commonly measured in terms of spatial area. ***Ecosystem condition is the quality of an ecosystem measured in terms of its abiotic and biotic characteristics.***

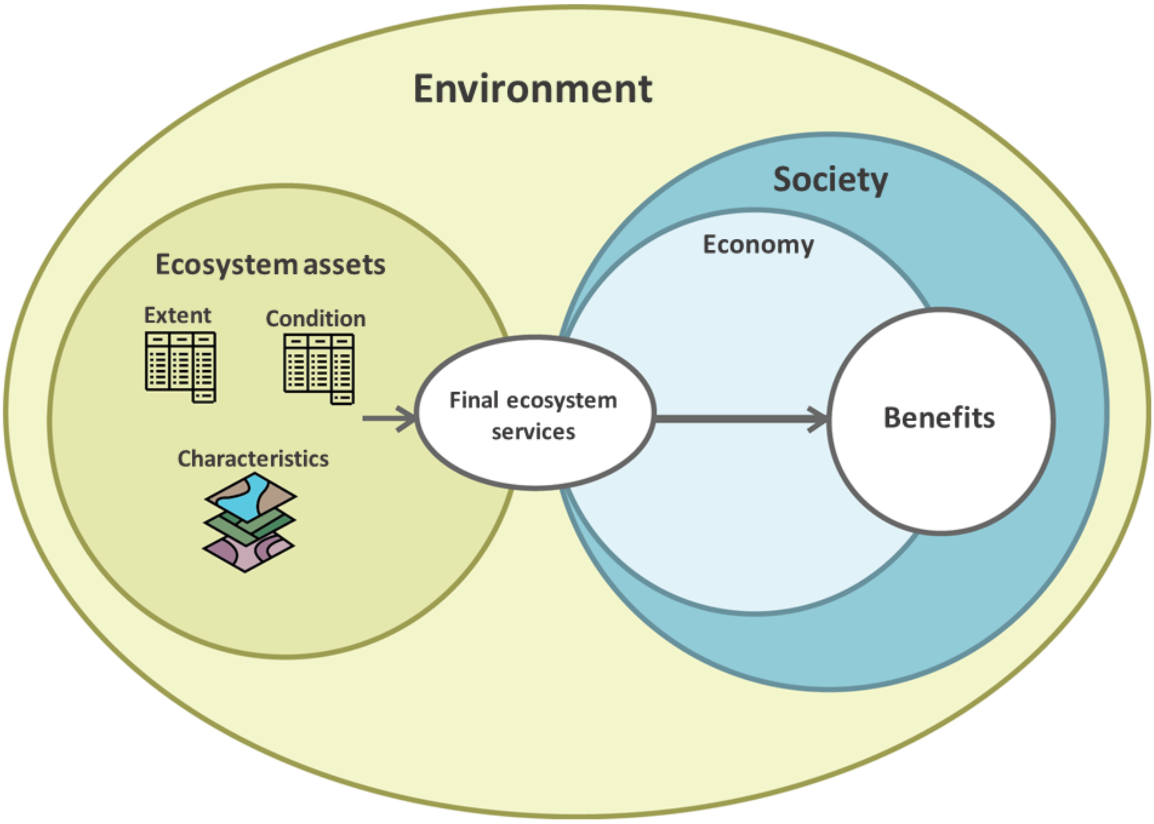
2.14 Ecosystem assets supply a bundle of ecosystem services that reflect various ecosystem characteristics and processes as well as the ecosystem type, the extent, condition and location of the asset, and the patterns of use by economic units (including households, businesses and governments). ***Ecosystem services are the contributions of ecosystems to the benefits that are used in economic and other human activity***. In this definition, use incorporates direct physical consumption, passive enjoyment and indirect use. Further, economic and other human activity encompasses all forms of interaction between ecosystems and people including both in situ and remote interactions.

2.15 ***Benefits are the goods and services that are ultimately used and enjoyed by people and society***. The benefits to which ecosystem services contribute may be captured in current measures of production (e.g., food, water, energy, recreation) or may be outside such measures (e.g., clean water, clean air, protection from floods).

2.16 In an accounting context, flows of ecosystem services are revealed in the sense of being observable interactions between economic units, people and ecosystems. Many of these interactions will not be reflected in exchanges in monetary terms, but nonetheless, some of the value of these interactions can be represented in monetary terms.

2.17 The relationships among these key components of ecosystem accounting are shown in Figure 2.1.

Figure 2.1: The general ecosystem accounting framework



2.18 The connection between the stock and flow components of the framework can be embodied in the concept of ecosystem capacity. In broad terms, the capacity of an ecosystem asset refers to the ability of an ecosystem to provide services into the future. Measures of ecosystem capacity with respect to ecological limits are therefore relevant and, in accounting terms, an ecosystem's capacity will underpin a store of future value.

2.2.4 Ecological considerations concerning the ecosystem accounting framework

2.19 Often ecosystems are perceived as more or less "natural" systems which are subject to only limited human influence. However, a wider interpretation is necessary based on the understanding that human activity is embedded within and influences ecosystems across the world. Different degrees of human influence can be observed. For instance, in a natural forest or wetland, ecosystem processes exert the dominant effect on the dynamics of the ecosystem and there are likely to be fewer impacts from human management of the ecosystem or from human disturbances. At the other end of the spectrum, for example, in intensively cultivated fields or in ponds where there is intensive aquaculture, ecosystem processes are heavily influenced by human management; and ecosystems close to, and within, areas of human settlement may be significantly affected by human activity and disturbances, such as pollution, but nonetheless retain some characteristics of functioning ecosystems. Ecosystem accounting encompasses ecosystem types across all of this spectrum in line with the broad scope of environmental assets as defined in the SEEA Central Framework.

2.20 Assessment of ecosystems should consider where ecosystems are located and how they function. Key spatial properties of an ecosystem's location are its extent, size or area, its spatial configuration (how its various components are arranged and organized within the ecosystem), the landscape or seascape forms[27] (e.g., mountain regions and coastal areas) within which the ecosystem is situated, and climate and associated seasonal patterns. Key properties of the functioning of an ecosystem are its abiotic components (e.g., mineral soil, air, sunshine and water), its biotic components (e.g., flora, fauna and micro-organisms), its structure (e.g., the trophic layers within the ecosystem), its processes (e.g., photosynthesis, decomposition), and its functions (e.g., recycling of nutrients and primary productivity).

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

2.22 It is widely recognized that ecosystems are subject to complex dynamics. The propensity of ecosystems to withstand pressures to change, or to return to their initial condition following natural or human impact, is called ecosystem resilience. The resilience of an ecosystem is not a fixed, given property, and may change over time, for example, owing to ecosystem degradation (e.g., through timber removal from a forest), ecosystem enhancement (e.g., through restoration of wetlands), or external effects (e.g., climate change). Other aspects of the complex dynamics of ecosystems are reflected in the presence of thresholds, tipping points and irreversibilities which are breached when ecosystem processes break down.

2.23 These complex dynamics and the associated non-linear relationships that are evident over multiple and intersecting time frames between the different ecosystem characteristics make the behaviour of ecosystems as a function of human and natural impacts difficult to predict, although there have been significant improvements in the understanding of those dynamics. The dynamics and relationships will be revealed through a time series of accounts that record measures of ecosystem extent and ecosystem condition. Further, the ecosystem services flow account will record the effects of changes in ecosystem dynamics over time in terms of changes in the supply and use of ecosystem services. Expected future flows of ecosystem services will be affected by expected ecosystem dynamics which should in turn affect assessments of ecosystem capacity and monetary values of ecosystem assets.

2.24 Understanding biodiversity is integral to assessment of the composition, structure and function of ecosystems. Following the CBD, ***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 of ecosystems***.[28] The SEEA EA incorporates data concerning aspects of ecosystem diversity and between-species diversity (commonly referred to as species diversity). The effects of levels of, and changes in, within-species diversity (commonly referred to as genetic diversity) will be implicit but not separately identified in ecosystem accounts.

2.25 The processes contributing to changes in biodiversity are many and varied. Nonetheless, some generic types of processes leading to such changes at the ecosystem and species level can be identified. At the ecosystem level, biodiversity loss is caused 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 and there is a

[27] A landscape or seascape (including those involving freshwater) is defined for accounting purposes as a group of contiguous, interconnected ecosystem assets representing a range of different ecosystem types.

[28] See CBD, article 2, entitled "Use of terms" https://www.cbd.int/convention/articles/?a=cbd-02

reduced capacity to maintain ecosystem function. The corollary is that increases in biodiversity, for example through habitat restoration or natural succession, are shown to lead to improvements in maintaining ecosystem function and increases in the resilience of ecosystems. The implications of these changes for flows of ecosystem services will depend on the context and will vary from service to service.

2.26 At the species level, biodiversity loss is characterized by a decrease in abundance of many endemic species existing in a particular area, while at the same time, some species, in particular those that benefit from disturbed habitats, increase in abundance. The extinction of the endemic species is often the final step in a long process of gradual reductions in abundance. In many cases, local or national species richness (i.e., the total number of species regardless of origin or abundance) increases initially because of the introduction or favouring of exotic species by humans.[29] However, because of these changes, ecosystems lose their regional endemic species and become more and more alike—a process described as "homogenization".[30]

2.2.5 Economic considerations concerning the ecosystem accounting framework

2.27 Ecosystem assets supply ecosystem services, either from a single ecosystem asset or by multiple ecosystem assets operating collectively. In this framing, ecosystem assets may be characterized as producing units. For accounting purposes, it is assumed that it is possible to attribute the supply of each ecosystem service to a single ecosystem type (e.g., wild fish provisioning services from a lake) or, where the supply of services involves more than one ecosystem asset of different ecosystem types (e.g., flood control services across a catchment), to estimate the contribution of each associated ecosystem type to the total supply.

2.28 Ecosystem services encompass a wide range of services and may be categorized into provisioning services (i.e., those related to the supply of food, fibre, fuel and water); regulating and maintenance services (i.e., those related to activities of filtration, purification, regulation and maintenance of air, water, soil, habitat and climate); and cultural services (i.e., the experiential and non-material services related to the perceived or realized qualities of ecosystems whose existence and functioning enables a range of cultural benefits to be derived by individuals). A reference list of ecosystem services for ecosystem accounting purposes is described in Chapter 6.

2.29 In many instances, the receipt of benefits by economic units involves a joint production process involving inputs from the ecosystem (i.e., ecosystem services) and human inputs including combinations of labour, produced assets, intermediate inputs (e.g., fuel, fertilizer) and individual's leisure time. Thus, for example, the ecosystem contribution to the growth of wild fish (which is reflected as being supplied by an ecosystem (e.g., lake) and used by an economic unit (e.g., a fisherman)) must be distinguished from the benefits which, in this example, are the fish sold by the fisherman to other economic units. Further, ecosystem accounting recognizes that the combination of inputs will vary. Thus, for example, where fish are sourced from aquaculture facilities, the ecosystem contribution will be significantly lower since much of the ecosystem contribution will have been substituted by produced inputs.

2.30 All ecosystem services reflect underlying ecosystem characteristics and processes such as nutrient cycling, photosynthesis or canopy cover but the SEEA EA does not aim to record systematically these characteristics and processes. Rather, the focus of ecosystem accounting is on the resulting supply of ecosystem services to economic units, including businesses and

[29] This is the so-called intermediate disturbance diversity peak see Lockwood & Mckinney (2001).
[30] See Lockwood & Mckinney (2001); Millennium Ecosystem Assessment (2005).

households. These are recorded as transactions between ecosystem assets (the suppliers) and economic units (the users) and are labelled final ecosystem services since they represent the final output of the ecosystem before interaction with the economy. For example, the supply of recreation-related services by local parks to households. For a supply of final ecosystem services to be recorded, there must be a corresponding use by an economic unit.

2.31 In addition, the ecosystem accounting framework supports the recording of flows of intermediate services which also reflect underlying ecosystem characteristics and processes but are flows of services between and within ecosystem assets. Recording these flows supports an understanding of the dependencies among ecosystem assets, for example, within a water catchment.

2.32 The definition of ecosystem services and the approach to their recording is designed to support integration of ecosystem accounting data with data on the production of goods and services that is currently recorded in the standard national accounts. In effect, ecosystem accounting recognizes a set of flows that are not recorded within the current production boundary of the SNA. The approach taken provides the opportunity to compile broader measures of output, income and consumption.

2.33 Recognizing ecosystems as stores of value concerning future flows of ecosystem services, invokes three points for discussion. First, it allows making the connection between the extent and condition of ecosystem assets and the potential for these ecosystem assets to supply services and associated benefits into the future and for future generations. This connection can be embodied in the concept of ecosystem capacity and is also related to concepts of option and insurance value provided by ecosystems. These topics are discussed in greater detail in Chapter 6.

2.34 Second, recognizing a store of value highlights the importance of investment in, and management of ecosystem assets to underpin the future supply of ecosystem services. There may be a wide range of motivations for undertaking investment in ecosystem assets and there is a range of ways in which accounts can present data to show the connection between ecosystem assets and those economic units that undertake this investment.

2.35 Third, recognizing a store of value opens a discussion on the scope of value or values that should be considered in relation to ecosystems recognising that no single perspective provides a complete view. Ecosystem accounting accommodates a perspective founded on accounting and economic principles wherein the value of an ecosystem is embodied in the expected future flows of services. While this perspective is useful in some contexts, it does not, and cannot, provide a complete perspective on the value of ecosystems to society. Section 2.4 on the framing of values for ecosystem accounting discusses this topic at more length.

2.3 The set of ecosystem accounts

2.3.1 Ecosystem accounts

2.36 The SEEA EA consists of a system of integrated *ecosystem accounts*. These constitute the heart of the ecosystem accounting system. The SEEA EA also describes *related accounts and presentations*, which provide for complementary presentations, connections to the SNA and SEEA Central Framework, and accounting information for policy relevant themes. These various accounts and presentations are summarized in this section.

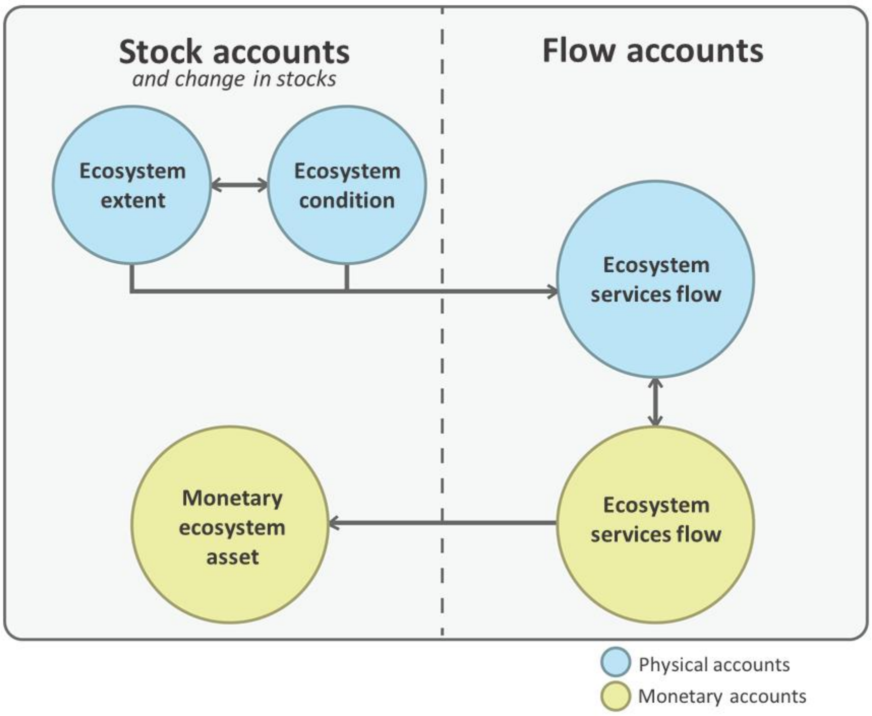
2.37 There are five ecosystem accounts as listed in Table 2.1. These five accounts constitute an accounting system where the accounts are strongly interconnected and provide a comprehensive and coherent view of ecosystems. There is no single, all-encompassing ecosystem account and, while designed as a system of integrated accounts, each account has merit and information in its own right.

Table 2.1: The ecosystem accounts

1	Ecosystem extent account – physical terms
2	Ecosystem condition account – physical terms
3	Ecosystem services flow account – physical terms
4	Ecosystem services flow account – monetary terms
5	Monetary ecosystem asset account – monetary terms

2.38 The logic underpinning the connections between the various ecosystem accounts is articulated in Figure 2.2. In terms of compilation, there will be particular connections between (i) the focus of the ecosystem extent account and the ecosystem condition account on the description of ecosystem characteristics; (ii) these two accounts and the ecosystem services flow account in physical terms since the characteristics of an ecosystem will influence the supply of ecosystem services; (iii) the ecosystem services flow accounts in physical and monetary terms through the use of data on the prices of ecosystem services; and (iv) the ecosystem services flow account in monetary terms and the ecosystem monetary asset account since the latter requires estimation of future flows of ecosystem services. Given all of these connections, supporting the coherence of various ecological and economic data is a core feature of ecosystem accounting.

Figure 2.2: Connections between the ecosystem accounts



2.39 **Ecosystem extent accounts** organize data on the extent or area of different ecosystem types. Data from extent accounts can support the derivation of indicators of composition and change in ecosystem types and thus provide a common basis for discussion among stakeholders including discussions related to conversions between different ecosystem types within a country. Compilation of these accounts is also relevant in determining the appropriate set of ecosystem types to underpin the structure of other accounts. Chapter 3 describes how ecosystem assets are delineated, including the classification of the various ecosystem types. Ecosystem extent accounts are discussed in Chapter 4. A stylized ecosystem extent account is shown in Table 2.2.

Table 2.2: Stylized ecosystem extent account (area)

	Stylized ecosystem types						
Accounting entries	Forests	Lakes	Cropland	Urban areas	Wetlands	Seagrass	**Total**
Opening extent							
Additions to extent							
Reduction to extent							
Closing extent							

2.40 **Ecosystem condition accounts**. A central feature of ecosystem accounting is its organization of biophysical information on the condition of different ecosystem types. The ecosystem condition account organizes data on selected ecosystem characteristics and the distance from a reference condition to provide insight into the integrity of ecosystems. It can also organize data relevant to the measurement of the capacity of an ecosystem to supply different ecosystem services. A stylized ecosystem condition account that records opening and closing condition indices for different ecosystem types and changes in the condition indices by type of condition characteristic is shown in Table 2.3. The compilation of the ecosystem condition account and the derivation of indices is described in Chapter 5.

Table 2.3: Stylized ecosystem condition account (condition indices)

	Stylized ecosystem types					
Accounting entries	Forests	Lakes	Cropland	Urban areas	Wetlands	Seagrass
Opening condition value						
Change in abiotic ecosystem characteristics (physical and chemical state)						
Change in biotic ecosystem characteristics (composition, structure and function)						
Change in landscape/seascape characteristics						
Net change in condition						
Closing condition value						

2.41 **Ecosystem services flow accounts – physical terms.** The supply of final ecosystem services by ecosystem assets and the use of those services by economic units, including households, enterprises and government, constitute one of the central features of ecosystem accounting. Using a supply and use table structure, the ecosystem service flow accounts record the flows of final ecosystem services supplied by ecosystem assets and used by economic units during an accounting period, and also allow for the recording of intermediate service flows between ecosystem assets. Chapter 6 describes ecosystem services concepts and the reference list of ecosystem services. Chapter 7 discusses the ecosystem services flow account in physical terms.

2.42 **Ecosystem services flow accounts – monetary terms.** Commonly, estimates of ecosystem services in monetary terms are based on estimating prices for individual ecosystem services and multiplying through by the physical quantities recorded in the ecosystem services flow account in physical terms. Conceptual and measurement definitions and treatments on the monetary valuation of ecosystem services is discussed in Chapters 8 and 9. A stylized ecosystem services flow account structure is shown in Table 2.4.

Table 2.4: Stylized ecosystem services flow account (physical units or currency)

Accounting entries	Types of economic units				Stylized ecosystem types						Total
	Industries	Gov.	House -holds	Rest of the world	Forests	Lakes	Cropland	Urban areas	Wet- lands	Seagrass	
Supply of ecosystem services											
Provisioning services											
Regulating & maintenance services											
Cultural services											
Use of ecosystem services	Final ecosystem services (used by economic units)				Intermediate services (used by ecosystem assets)						
Provisioning services											
Regulating & maintenance services											
Cultural services											

2.43 **Monetary ecosystem asset accounts**. Asset accounts are designed to record information on stocks and changes in stocks (additions and reductions) of assets. The ecosystem monetary asset account records this information in monetary terms for ecosystem assets based on the monetary valuation of ecosystem services and applying the net present value approach to obtain values in monetary terms for ecosystem assets at the beginning and end of each accounting period. The measurement of changes in asset values due to, for example, ecosystem enhancement, ecosystem degradation and ecosystem conversion are also included in this account. These accounts are described in Chapter 10. A stylized monetary ecosystem asset account is shown in Table 2.5.

Table 2.5: Stylized monetary ecosystem asset account (currency)

Accounting entries	Stylized ecosystem types						Total
	Forests	Lakes	Cropland	Urban areas	Wetlands	Seagrass	
Opening value							
Ecosystem enhancement							
Ecosystem degradation							
Ecosystem conversions							
Other changes							
Net change in value							
Closing value							

2.3.2 Related accounts and presentations

2.44 The ecosystem accounts provide an integrated and comprehensive view of ecosystems in both physical and monetary terms. Nonetheless, for both compilation and analytical purposes, there are number of additional, related accounts and presentations that may be appropriate for monitoring and analysis in different circumstances. These accounts and presentations are grouped broadly into four types: (i) extended economic accounts; (ii) complementary valuations; (iii) thematic accounts; (iv) combined presentations and indicators.

2.45 **Extended economic accounts**. Using national accounting principles, data from the ecosystem accounts can be used to complement the standard economic accounts of the SNA concerning the measurement of economic production, the generation of income, capital formation and wealth. Thus, extended supply and use tables, extended balance sheets and extended sequence of institutional sector accounts can all be compiled, including associated aggregate measures of income and wealth adjusted for the enhancement and degradation of ecosystem assets. These accounts are described in Chapter 11.

2.46 **Complementary valuations**. In serving as the basis for the integration of ecosystem data with the accounts of the SNA, the ecosystem accounting framework incorporates a range of measurement choices, particularly as regards the scope of ecosystem services, the use of the exchange value concept for monetary valuation and the attribution of degradation to the economic unit who suffers from the loss of ecosystem condition. It is possible to design complementary valuations using different valuation concepts, measurement scopes and assumptions (e.g., concerning institutional arrangements) to support different policy and analytical purposes. Possible complementary valuations are discussed in Chapter 12.

2.47 **Thematic accounts** are accounts that organise data on themes of specific policy relevance. Examples of relevant themes include biodiversity, climate change, oceans and urban areas. In all of these cases, relevant data can be obtained from the ecosystem accounts but additional data can also be sourced from SEEA Central Framework and SNA accounts, for example concerning greenhouse gas emissions and resource management expenditure. Data not incorporated in accounts can also sometimes be used to support thematic accounting. For biodiversity and climate change, additional accounts are also relevant, namely species accounts and carbon accounts. The principles and design of thematic accounts are introduced in chapter 13.

2.48 **Combined presentations and indicators** are a means of collating and tabulating data on a selected set of variables from the ecosystem accounts and elsewhere to allow users to quickly see relationships of analytical significance. Within a standard accounts structure, there are often only a relatively limited set of key measures and these presentations provide a means to highlight relevant variables, particularly for the derivation of indicators. Indicators can be designed and selected in many ways and accounting frameworks provide a strong base for their derivation and coherence. These topics are discussed in Chapter 14.

2.4 Framing of values in ecosystem accounting

2.4.1 Introduction

2.49 The concepts and methods applied in SEEA EA reflect specific, well defined, objectives in recording the values related to ecosystems and ecosystem services. The primary objective is to consider ecosystems and ecosystem services in the context of economic measures of production, consumption and accumulation (wealth). In monetary terms, the SEEA EA records stocks and flows based on exchange values which are narrower in scope than other monetary values concerning the environment that often encompass measures of consumer surplus and non-use values.

2.50 At the same time, the SEEA EA's integration of both physical and monetary data allows it to provide data that is relevant in supporting assessments based on other value perspectives. Further, the SEEA EA demonstrates how physical data, for example on ecosystem extent and condition, can be used in macro-economic policy and decision making. Thus, beyond the primary objective noted above, data from the accounts will be relevant in a range of other contexts such as sustainability and environmental reporting, spatial planning and environmental management, and the assessment of financial risks particularly where it concerns the integration of environmental and economic considerations.

2.51 It is recognized that the concepts and methods of ecosystem accounting cannot encompass all value perspectives concerning ecosystems. Hence, the data from ecosystem accounts should not be considered to provide a holistic, complete or full societal value of nature; or reflect all of the multiple value perspectives on ecosystems.

2.52 This section does not aim to provide a definitive summary of the literature or to establish a SEEA EA values perspective. Rather, this section places ecosystem accounting in a broader values context. This can support an understanding of the different ways in which ecosystems can be valued; support appropriate interpretation and application of ecosystem accounting data and indicate types of analysis that ecosystem accounting supports, but does not incorporate, for example, cost-benefit analysis and the assessment of non-use values.

2.4.2 Summary of multiple value perspectives about nature

2.53 Section 2.2 described five measurement perspectives for ecosystems. In a similar way, there are multiple perspectives on the value of ecosystems recognizing that each one retains a focus on the same concept of an ecosystem. The purpose of value frameworks is to place the various perspectives in a common context and hence allow different analysts and decision makers to see how their views may align or differ.

2.54 Two continuums are commonly used to reflect value perspectives: (i) the continuum from anthropocentric to non-anthropocentric values; and (ii) the continuum from instrumental to intrinsic and relational values. The following definitions from Pascual et al. (2017) are used to support discussion here.

- *Anthropocentric values* are those that are centred on human beings;
- *Non-anthropocentric values* are those that are centred on the environment;
- *Instrumental value* is the value attributed to something as a means to achieve a particular end;
- *Intrinsic value* refers to inherent value, that is the value that something has independent of any human experience or evaluation. Such a value is viewed as an inherent property of the entity (e.g., an organism) and not ascribed or generated by external valuing agents (such as human beings); and
- *Relational values* are values relative to the meaningfulness of relationships, including the relationships between individuals or societies and other animals and aspects of the life world, as well as those among individuals articulated by formal and informal institutions.

2.55 Various researchers have posited different combinations of these values to describe various frameworks of values. Particular examples include the Total Economic Value (TEV) framework (Pearce & Turner, 1990; TEEB, 2010); the work of Turner et al. (2003), the IPBES values framework (Díaz et al., 2015; Pascual et al., 2017); the work of Polasky & Segerson (2009) and the more recent life framework of values (O'Connor & Kenter, 2019; O'Neill et al., 2008). A comprehensive assessment of these and other value frameworks and perspectives is being conducted by IPBES.[31]

2.56 Significantly, these different value perspectives are not in some manner additive, i.e., it should not be concluded that, by recognizing all types of value, an aggregate value of nature could be obtained. Rather, it is more appropriate to consider that, for a given ecosystem, each value perspective will provide a different value – i.e., there are multiple, potentially incommensurate, values to be compared and contrasted in decision making. Importantly, all

[31] For more information on the IPBES Values assessment see: https://ipbes.net/values-assessment.

of these values and associated frameworks recognise that the environment has value beyond that reflected in monetary values.

2.57 While these value concepts are overlapping and nested, a statistical framing of data about ecosystems may be able to play an important role in incorporating at least some parts of the wider value of ecosystems as a regular component of decision making. Indeed, an advantage of standardizing ecosystem accounting value concepts is that there is an agreed measurement definition which is stable over time. In turn, this can be used as a common basis for policy design and decision making.

2.4.3 Linking the ecosystem accounts and multiple value perspectives

2.58 In broad terms, the commonly understood focus of the SEEA EA is on values of anthropocentric origin – i.e., values that are centred on human beings. Further, measurement focus is commonly on instrumental or use values, in part because these interactions are most readily quantified and also because, from a monetary valuation perspective, these values are most readily reflected in monetary terms. From a policy perspective, the focus on anthropocentric, instrumental values may also be considered of high relevance since they concern the types of human interactions with the environment that can place the most pressure on ecosystems.

2.59 Ecosystem accounting data in monetary terms is valued using the concept of exchange values wherein ecosystem services and ecosystem assets are valued at the prices they are, or would be, exchanged on a market. This approach to monetary valuation facilitates comparison with the monetary values recorded in the national accounts. Chapter 8 describes the exchange value concept in more detail.

2.60 The monetary values in ecosystem accounting are limited in scope to the range of ecosystem services that are included in a given ecosystem account and the use of exchange values does not provide a broader monetary value that incorporates the direct and indirect benefits received from ecosystems including their non-use values. In this respect, monetary data from the ecosystem accounts, in line with the valuation basis used in the SNA, do not provide a comprehensive monetary value of well-being associated with ecosystems. Complementary approaches to monetary valuation are discussed in Chapter 12 and Annex 12.1 describes the relationship between exchange values and other economic valuation concepts.

2.61 It is common for the discussion of values and valuation in accounting to assume a singular focus on instrumental values expressed in monetary terms. However, since ecosystem accounting encompasses data in both physical and monetary terms, and also provides data that are spatially explicit, there is the potential for ecosystem accounting data to support discussion of a wider range of value perspectives.

2.62 Specifically, it is noted that data on ecosystem extent and ecosystem condition in physical terms will support discussion of a number of aspects of the intrinsic and non-anthropocentric perspectives on the value of nature. Further, data on flows of ecosystem services in physical terms will support discussion of instrumental values and some aspects of relational values. Data from accounts such as species accounts, carbon stock accounts and water resources accounts will also support these discussions.

2.63 Lastly, the assessment of multiple values often requires consideration of local contexts and a wide variety of users. Generally, ecosystem accounts are described for relatively large areas with multiple ecosystem types and for broad categories of users, e.g., households, businesses and governments. However, in principle the application of ecosystem accounting concepts can be undertaken at smaller scales (using higher resolutions of data for local administrative areas) and/or for particular social groups. For example, measurement may focus on the use of specific ecosystem services in individual locations; or be elaborated to highlight the uses of ecosystem services by households of different income levels. The potential to undertake such measurement will necessarily be subject to the availability of data.

2.64 Overall, while there is a primary focus on anthropocentric, instrumental values, the data from a set of ecosystem accounts will also be relevant in supporting assessments based on other value perspectives.

2.5 General national accounting principles

2.5.1 Introduction

2.65 Recording entries in the ecosystem accounts follows the general principles of national accounting as described in the 2008 SNA, Chapter 3. A summary of some of the aspects of most relevance to the SEEA EA is provided in the SEEA Central Framework, Chapter 2. These aspects concern: double and quadruple entry accounting, the time of recording, units of measurement, and valuation rules and principles.

2.66 This section describes the accounting principles that require particular consideration in the context of ecosystem accounting. The discussion of valuation principles is not described here. Chapters 8 and 9 provide more detail on the range of non-market valuation considerations that arise in ecosystem accounting.

2.5.2 Length of the accounting period and frequency of accounts

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

2.68 While one year may be suited to analysis of economic trends, analysis of trends in ecosystems may require information for varying lengths of time depending on the processes being considered. Even in situations where ecosystem processes can be analysed on an annual basis, the beginning and end of the year may well differ from the beginning and end of year that is used for economic analysis.[32]

2.69 Although considerable variation in the cycles of ecosystem processes exists, it is suggested that ecosystem accounting apply 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 the general integration of information is thus best supported through the use of this time frame.

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

2.71 Ideally, annual accounts would be compiled each year to provide a consistent time series of data. However, it is acknowledged that compiling ecosystem accounts with this level of

[32] For example, hydrologic years may not align with calendar or financial years.

regularity may not be possible during initial phases of implementation. Nonetheless, there should remain the general ambition of regular reporting of accounts, for example every 3 -5 years. A key factor that may limit the compilation of more frequent accounts is the availability of source data, for example concerning detailed maps of ecosystem types. In addition to considering the availability of alternative data sources, compilers may also consider the application of interpolation and extrapolation techniques that support in-filling of accounting periods not covered in benchmark or baseline data sets.

2.5.3 Time of recording

2.72 The general national accounting requirement is that transactions and other flows must be recorded as occurring at the same point in time in the various accounts for both units involved. In respect of ecosystem services, this implies that the supply of ecosystem services must be recorded in the same accounting period as the use of those services. It is noted that the timing of the transaction may be different from when an ultimate benefit is received. For example, the benefits of global climate regulation services will occur well after the associated carbon sequestration itself takes place. In this regard, recall that the focus of ecosystem accounting is recording the supply and use of ecosystem services rather than the well-being or outcomes that eventuate.

2.73 Measures of ecosystem assets should relate to the opening and closing dates of the 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, an understanding of relevant shorter seasonal and longer natural cycles will be required.

2.5.4 Units of measurement

2.74 In the measurement of stocks, the entries will relate to a unit of measure at a point in time, e.g., total area, total volume. In the measurement of flows, the entries will relate to a unit of measure per unit of time, e.g., cubic metres per year. The unit of time that is appropriate will depend on the selected length of the accounting period.

2.75 For accounts compiled in monetary terms, all entries in the accounts must be measured in terms of money, i.e., currency units.

2.76 For accounts compiled in physical terms, the units of measurement will vary and will depend on the account and the relevant variable. In ecosystem extent accounts a common unit of area, such as hectares, is recommended to allow for the relative size and composition of ecosystem types within an ecosystem accounting area to be assessed. Using a common unit of area also ensures that accounting balances and aggregations can be applied for this account.

2.77 In ecosystem condition accounts, each characteristic and associated variable is likely to involve use of different measurement units. These are normalised using reference levels and reference conditions and hence can be compared with each other. However, there is no natural aggregation across characteristics without the use of appropriate weighting or aggregation approaches.

2.78 In ecosystem services flow accounts in physical terms, different ecosystem services are recorded in different measurement units. Given the structure of these flow accounts, it is possible to aggregate across columns for a single service to provide an estimate of total supply or total use of that service. However, it is not possible to aggregate across different ecosystem services, i.e., over rows, to provide total supply or use of ecosystem services for an ecosystem type or type of economic unit. Depending on the analytical purpose, this is one motivation for the use of a standard money metric.

2.79 In measuring supply and use, it is fundamental that the same measurement unit be applied for both supply and use of a single ecosystem service in physical terms. Thus, if the supply of a service is measured in tonnes per year, then the use of that service must also be measured in tonnes per year. This allows balancing of supply and use for individual ecosystem services and related reconciliation.

2.5.5 Gross and net recording

2.80 The terms “gross” and “net” are used in a number of accounting situations. In ecosystem accounting, the recording of ecosystem services is undertaken such that all flows between ecosystem assets and economic units are explicitly identified, i.e., the recording is in gross terms for both physical and monetary measures. Thus, for example, final ecosystem services are recorded as the output of ecosystem assets and inputs to an economic unit (e.g., biomass provisioning services to agricultural units). In the case of SNA benefits, there will be a related transaction between two economic units (e.g., sale of agricultural outputs from the agricultural unit to a manufacturer). No double counting is implied in this treatment since the recording of the final ecosystem service is offset by the recording of the input to the economic unit. For non-SNA benefits where there is no corresponding output, the recording involves showing a flow of final ecosystem services from an ecosystem asset and use by an economic unit (e.g., flows of air filtration services). These recording principles can be demonstrated using supply and use table presentations which are elaborated in Chapter 7.

2.81 In the monetary valuation of ecosystem services, the relevant values should be calculated such that the costs incurred by economic units of using or accessing the ecosystem services are deducted, i.e., they are “net” of costs. This issue arises when the valuation method being applied uses an observed market price and therefore deducting these costs is required to ensure that the monetary valuation is focused on the contribution of the ecosystem. Further discussion on these valuation issues is in Chapter 9.

2.82 In other situations, the term “gross” is used to indicate that an accounting aggregate (e.g., GDP) has not been adjusted for the costs of using capital, i.e., that measures of depreciation, depletion and degradation have not been deducted. In other situations, the term is used simply to refer to the difference between two accounting items, e.g., net lending which is the difference between a sector’s transactions in financial assets and the incurrence of liabilities.

2.5.6 Scale of application

2.83 The ecosystem accounting framework and associated accounts have been designed with the intent of being applied at national (or large sub-national) scale, i.e., in the context of multiple ecosystem assets (across the variety of ecosystem types within an ecosystem accounting area) and for multiple ecosystem services. This is analogous to the general application of the national accounts, which covers the activities of all industries resident within an economic territory.

2.84 It is recognized, however, that the application of the ecosystem accounting framework may also have a more tailored focus. For example, the framework may be applied for measurement of:

- A single ecosystem asset or ecosystem type (e.g., a wetland or wetlands) and/or a single ecosystem service (e.g., water regulation). For individual provisioning services, there may be a direct connection to natural resource accounting, as described in Chapter V of the SEEA Central Framework.
- A single ecosystem asset or ecosystem type and multiple ecosystem services. Accounting at this scale may be of interest in the management of specific ecosystems or ecosystem types (e.g., wetlands).
- Multiple ecosystem types and a single ecosystem service. Accounting of this type may be of interest for monitoring and understanding the dynamics of the supply of a specific service across a broad spatial area (e.g., water regulation, global climate regulation).
- Areas of land within a country that have common land-use or land management arrangements or be the focus of integrated land management practices (e.g., watersheds, national parks).

2.85 The logic of the ecosystem accounting framework described above can be applied in all of these reduced or tailored cases, since the accounting principles themselves are scale independent. Moreover, to the extent that individual projects focus on these more tailored accounts, it should be possible to integrate the findings within a broader project covering multiple ecosystem assets and services. The potential for integration is heavily dependent on the adoption of consistent measurement boundaries and classifications, which would then become a prime motivation for application of a common ecosystem accounting framework.

2.5.7 Data quality and scientific accreditation

2.86 The concept of data quality for official statistics is a broad-ranging one, encompassing factors of relevance, timeliness, accuracy, coherence, interpretability, accessibility and the quality of the institutional environment in which the data are compiled. The development of statistical 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.

2.87 In ecosystem accounting, it is likely that a reasonable proportion of the information used will be drawn from disparate data sources, possibly developed to provide information for various scientific, research, management and administrative purposes rather than primarily for statistical purposes. Administrative data sets are often produced and analysed with a focus on smaller or borderline cases rather than on those cases that may be the most statistically significant. Some ecological data are similarly treated. For example, data on the quality of water may be collected for areas where there is a known pollution problem rather than to provide broad coverage and a representative sample of water quality. Care must therefore be taken to ensure that, as far as possible, the data used is representative of all contexts within the accounting scope.

2.88 It is also likely that information for ecosystem accounting will be drawn from various independent studies in the biophysical sciences and economics literature. This being the case, appropriate review and validation of the data will be required, for example considering the various measurement concepts and scopes that have been applied, to ensure that the data are suitable for the purposes of ecosystem accounting and that coherence across the accounts can be obtained.

2.89 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 IMF's Data Quality Assurance Framework (DQAF),[33] are applicable to biophysical data as well as socioeconomic data. These frameworks are tools designed to assure that data are collected and compiled according to international standards and are subject to appropriate quality assessment procedures.

2.5.8 Uncertainty in measurement

2.90 There are a number of 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 assets; (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.

2.91 *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 often service 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 aggregated information related to flows of provisioning services are generally, readily available.

2.92 *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.

2.93 *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.

2.94 *Uncertainty regarding future prices and values of ecosystem services*. Pricing benefits and costs that may accrue in the future is complex because it is extremely difficult to predict our circumstances in the future. The implications of humanity's continuing modification of the climate and ecosystems 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 non-market valuation compound errors in estimation.

2.95 The strategies to deal with the various sources of uncertainty will vary by country as a function of data availability and relevant services selected for ecosystem accounting. The approaches to limiting these uncertainties and maximising the robustness of the data in ecosystem

[33] See https://dsbb.imf.org/dqrs/DQAF.

accounts will need to be further developed once more practical experience with ecosystem accounting has been gathered and evaluated. The experiences gathered at both national and sub-national levels will be relevant in this context and thus it is important that all accounting work documents the scope of measurement, definitions applied, methods used and assumptions made.

SECTION B: Accounting for ecosystem extent and condition

Section overview

Ecosystem assets are at the heart of the ecosystem accounting framework described in Chapter 2. SEEA EA Section B, encompassing Chapters 3, 4 and 5, describes the approach to structuring data about ecosystem assets. In the first instance, this involves delineating ecosystem assets which are represented as spatial units. This step allows accounting for the extent of ecosystems and how their size and configuration is changing over time. In a second step, the condition of ecosystem assets is assessed using a focus on their integrity.

The measurement of the extent and condition of ecosystems is a common focus of environmental data. Generally, speaking there is a wealth of data in this domain. Unfortunately, a common feature of these data is that they are not co-ordinated and are difficult to use to convey an integrated picture of changes, especially across multiple ecosystem types and at national level. The intent in ecosystem accounting is to provide a common structure and approach for the integration of the relevant information on the size and condition of ecosystems.

The approach to delineating ecosystem assets described in Chapter 3 also provides the underlying statistical basis for the organisation of data about ecosystems in a comprehensive and mutually exclusive way. In this respect, the spatial units that are delineated are analogous to the economic units that are delineated for the purposes of economic statistics, usually in the form of a business register. Much of the underlying data co-ordination work involved in ecosystem accounting is focused on attributing data about different characteristics to ecosystem assets and ecosystem types.

The co-ordination of data on ecological characteristics using statical and accounting principles is an important extension of the wider SEEA approach that recognises the significance of non-monetary data in describing the relationship between the environment and the economy. While accounting for extent and condition does support the measurement of ecosystems in monetary terms, as described in Section D, data from the ecosystem extent and ecosystem condition accounts is of direct relevance, particularly in understanding the effects of human activities on ecosystems and in assessing the distance from ecological thresholds. Further, data on ecosystem extent and condition are a means to consider the intrinsic value of ecosystems, i.e., without consideration of the relative importance of ecosystems to people.

Taken together, these various features of accounting for ecosystem extent and condition, imply that these accounts are a central feature of ecosystem accounting and should be a core part of SEEA EA implementation in all contexts.

3 Spatial units for ecosystem accounting

3.1 Introduction

3.1 A key feature of ecosystem accounting is its ability to integrate spatially referenced data about ecosystems, i.e., data about the location, size and condition of ecosystems within a given area and how these are changing over time. Recording these stocks and changes in stocks in a coherent and mutually exclusive manner supports the derivation of indicators (for example, the rate of change in forest or grassland areas relative to the rate of change in cultivated areas).

3.2 For accounting purposes, different ecosystems are treated as spatial units. The delineation of ecosystems into spatial units requires careful consideration of various ecosystem characteristics across the various ecological realms, including terrestrial, freshwater, marine and subterranean ecosystems. The present chapter outlines the approach used in the SEEA EA to define, classify and delineate spatial units. Section 3.2 describes the different types of spatial units used in ecosystem accounting while sections 3.3 and 3.4 present the general principles and practical considerations for the delineation and classification of spatial units for ecosystem accounting purposes.

3.3 The availability of spatial data to describe ecosystems and their economic uses and associated beneficiaries is an important consideration in the compilation of ecosystem accounts. The spatial and thematic detail of these data, as well as their geospatial comparability and integration into a shared spatial data infrastructure, influences the richness of ecosystem accounts that can be compiled. This issue is discussed in section 3.5.

3.4 Data on the size and changes in size of ecosystems are recorded in ecosystem extent accounts, and their location and configuration can be presented in maps. Understanding the size and location of ecosystems supports the measurement of ecosystem condition and the measurement and valuation of many ecosystem services, the flows of which will vary from ecosystem to ecosystem. These matters are discussed in later chapters.

3.2 Types of spatial units

3.2.1 Ecosystem assets

3.5 The primary spatial units for ecosystem accounting are labelled ecosystem assets. ***Ecosystem assets (EAs) are contiguous spaces of a specific ecosystem type characterized by a distinct set of biotic and abiotic components and their interactions.*** The definition of ecosystem assets is a statistical representation of the general definition of ecosystems from the CBD.[34]

3.6 Ecosystem assets play a key role in ecosystem accounting. They are the statistical units for ecosystem accounting, i.e., the ecological entities about which information is sought and about which statistics are ultimately compiled. This includes information concerning their extent, condition, the ecosystem services they provide and their monetary value. Each ecosystem asset is classified to an ecosystem type***. An ecosystem type reflects a distinct set of abiotic and biotic components and their interactions***. Components include, for example, the animals, plants, fungi, water, soil, minerals present in ecosystems. Annex 3.1 provides an

[34] See CBD definition of ecosystems in Chapter 2, para. 2.6.

introduction to a range of ecological concepts and terms, including ecosystems, habitats, biomes, ecoregions and the various general drivers and characteristics of ecosystems.

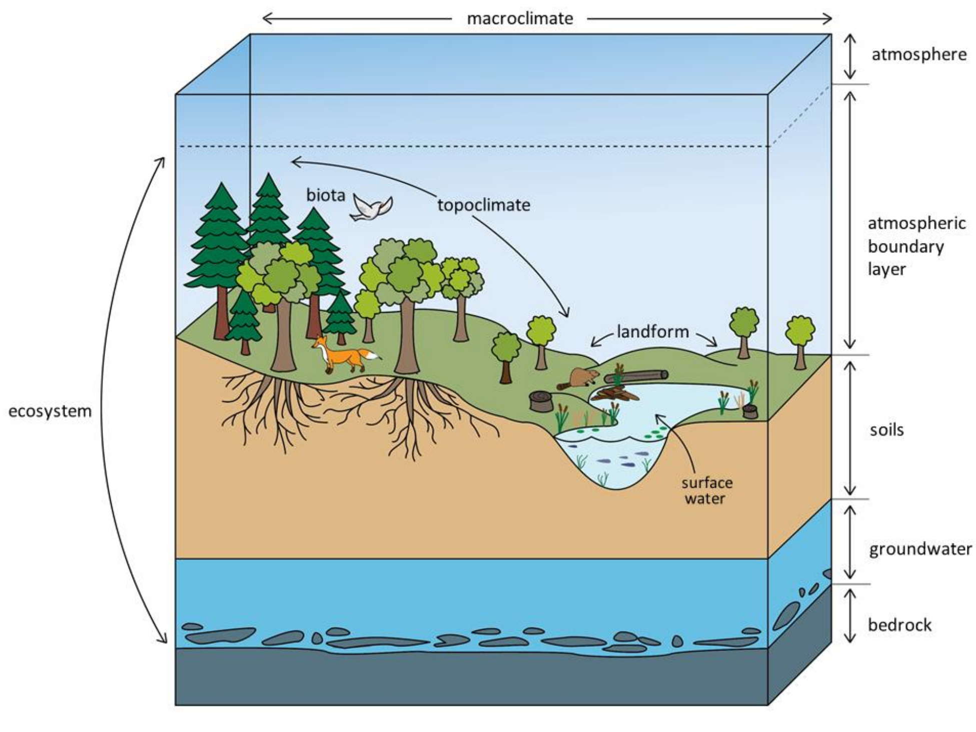
3.7 The statistical outputs from ecosystem accounting are most commonly presented either in tabular form where data on ecosystem assets are grouped according to their ecosystem type; or in the form of maps where individual ecosystem assets are reflected and the configuration and location of different ecosystem types can be displayed.

3.8 The SEEA Central Framework defines environmental assets as "*the naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity*" (SEEA Central Framework, para. 2.17). This definition encompasses ecosystems. As for environmental assets, ecosystem assets are considered assets on the basis of their biophysical existence and are not dependent on establishing flows of benefits or ownership as is required for economic assets in the SNA.[35]

3.9 Conceptually, ecosystem assets are envisaged as three-dimensional spaces (see Figure 3.1 and Figure 3.2). While many ecosystems in the terrestrial, freshwater and marine realms are all located close to the Earth's surface, they all have three dimensional characteristics.

3.10 For example, for terrestrial systems, the biotic components usually extend from the plant roots below the surface to the vegetation growing above the surface. The abiotic components are those components that directly interact with these living components: the soil, the surface and soil water, and also the air from the atmosphere.

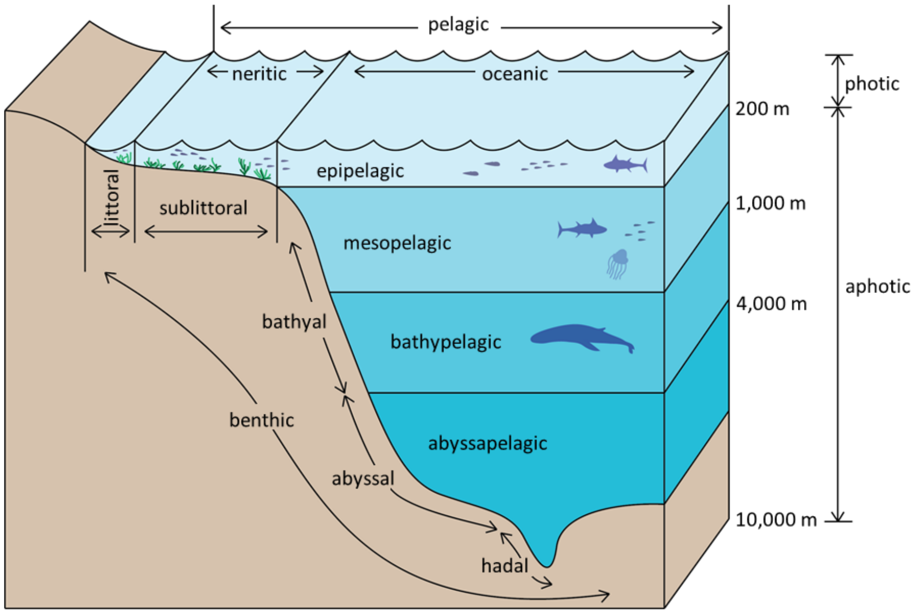
Figure 3.1: Vertical structure of a terrestrial ecosystem



Source: Adapted from Bailey et al. (1996).

[35] As discussed in Chapter 11, establishing the economic ownership of ecosystem assets and attributing benefits is required for the integration of ecosystem accounting data with economic accounts noting that ecosystem accounts can be compiled in the absence of this information.

Figure 3.2: Vertical structure of marine ecosystems



Source: Adapted from Kingsford (2018).

3.11 Marine ecosystems. Marine ecosystems are not concentrated near one surface (i.e., the air-land/water interface) but extend throughout the water column and include the underlying sediment and seabed which provides a natural boundary for the ecosystem assets (see Figure 3.2). In concept, ecosystem assets for marine ecosystems could be delineated by taking into account various ecological differences with respect to, for example, salinity, temperature, nutrients and both location and depth within the water column, and distinguishing the seabed from the overlying water column.

3.12 However, since it may be difficult to delineate ecosystem assets in a vertically stratified manner, delineation based on surface area is likely the most practical measurement pathway for accounting purposes. In particular, for marine ecosystems within the continental shelf,[36] it is recommended to delineate ecosystem assets based on the areas of different ecosystem types associated with the seabed – e.g., seagrass meadows, subtidal sandy bottoms and coral reefs.

3.13 Atmospheric boundary. Several important ecological processes are based on the interaction with the atmosphere, including respiration, nitrogen fixation, and those associated with the impact of air pollution on vegetation and fauna such as air filtration. To establish a clear boundary for accounting, the atmosphere directly above and within an ecosystem is considered part of the ecosystem asset as one of the abiotic components within the spatial unit.

3.14 The interaction between the Earth's surface and its ecology, and the atmosphere is limited to the atmospheric boundary layer. For accounting purposes, this forms the natural upper boundary of ecosystem assets. The atmospheric boundary layer is defined as the bottom layer

[36] The continental shelf is that part of the continental margin which is between the shoreline and the shelf break or, where there is no noticeable slope, between the shoreline and the point where the depth of the superadjacent water is approximately between 100 and 200 metres.

of the troposphere that is in contact with the surface of the earth (American Meteorological Society, 2020). Parts of the atmosphere above this layer are not considered ecosystem assets.

3.15 While the atmosphere satisfies the general definition of an environmental asset in the SEEA Central Framework (para. 2.17) and flows of emissions to the atmosphere can be recorded in physical supply and use tables, the volume of air in the atmosphere is not included in the measurement scope of environmental assets (SEEA Central Framework, para 5.16). Further discussion on a more complete accounting treatment for the atmosphere is part of the SEEA EA research agenda including the consideration of the atmosphere as a separate environmental asset.

3.16 Subsoil boundary. The subsoil that is directly involved with ecosystem processes is considered part of the ecosystem asset. This holds for terrestrial (soil), freshwater and marine ecosystems (sediments). These ecosystem processes include water flows between soil layers and aquifers, bioturbation, carbon cycling, the cycling of nutrients, other diagenetic processes, etc. The precise sub-soil boundary layer for an ecosystem asset will be dependent on the structure of the soil, sediment and bedrock.

3.17 Aquifers. All aquifers, both confined and unconfined, will contain some biotic components and are treated as ecosystems. Confined aquifers should be treated as distinct ecosystem assets from the ecosystem assets located above them. Unconfined aquifers may be treated distinctly or integrated with the surface ecosystem asset depending on the context.

3.18 Subterranean ecosystems. There are a variety of subterranean ecosystems including caves and underground streams. These ecosystems satisfy the general conceptual definition of ecosystem assets in having a distinct set of biotic and abiotic components.

3.19 Subsoil abiotic resources. Resources located in the deeper substrate within the lithosphere, such as natural gas, oil and coal, and mineral ores, that have no direct interaction with the surrounding ecosystems, are not considered ecosystem assets, but are included in the broader definition of environmental assets.

3.2.2 Applying the conceptual boundary for ecosystem assets

3.20 Although ecosystem assets are conceptually three-dimensional (3D), they have a two-dimensional (2D) boundary or footprint. This footprint is defined by the intersection of the 3D bounding envelope of the ecosystem asset with the earth's surface. The sides of this envelope are assumed to be vertical, such that the resulting footprints of adjacent ecosystem assets do not overlap. In practice therefore, for most accounting purposes, ecosystem assets are represented in two dimensions by their area.

3.21 For those ecosystem assets that are located below surface level terrestrial and freshwater ecosystems, such as subterranean ecosystems and aquifers, it is also possible to define their footprint in 2D terms. However, since these areas will co-exist with the areas of other ecosystem assets closer to the Earth's surface, their extent should be accounted for separately depending on analytical requirements.

3.2.3 Ecosystem accounting areas

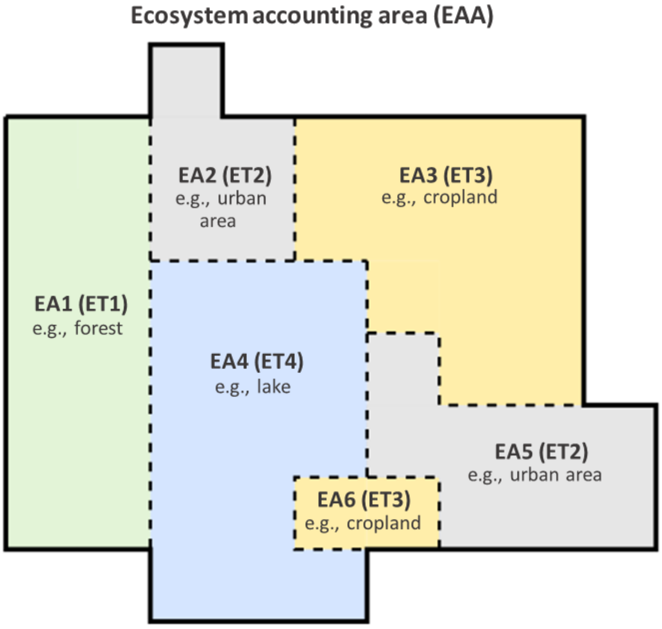
3.22 The second type of spatial unit for ecosystem accounting is the ecosystem accounting area. The ***ecosystem accounting area (EAA) is the geographical territory for which an ecosystem account is compiled.*** The EAA therefore determines which ecosystem assets are included in an ecosystem account.

3.23 An EAA is a two-dimensional construct providing an accounting boundary around a set of ecosystem assets represented by their two-dimensional footprints, such that the sum of the areas of the ecosystem assets is equal to the total area delineated by the EAA.

3.24 The relationships between the spatial units are presented in mapped form in Figure 3.3 for a stylized context. In this figure, a combination of six different ecosystem assets (EA1 – EA6) are shown as located within an EAA. Each EA is classified to a different ecosystem type (ET1 – ET4). A single ecosystem asset (EA) can only be assigned to a single ecosystem type (ET) but there can be multiple occurrences of a single ET within an EAA.

3.25 The same relationships can also be presented in tabular form where, at a given point in time, the sum of the areas of different ET will be equal to the total EAA. This is shown in Table 3.1, which provides the basic entry point to accounting for ecosystem extent as discussed in Chapter 4.

Figure 3.3: Relationships between spatial units in ecosystem accounting



Note: EA: Ecosystem assets; ET: Ecosystem type

Table 3.1: Tabular presentation of spatial units

Spatial unit	Size*
Ecosystem type #1 (EA1)	12
Ecosystem type #2 (EA2 & EA5)	13
Ecosystem type #3 (EA3 & EA6)	15
Ecosystem type #4 (EA4)	14
Ecosystem Accounting Area (EAA)	**54**

Note: * Any measurement unit for area may be used, including for example hectares and square kilometres.

3.26 Common forms of EAA are:

i. National jurisdictions and groups of countries (e.g., countries of the European Union);

ii. Sub-national administrative areas (e.g., state, province);

iii. Environmentally defined areas within a country (e.g., water catchments, ecoregions) or across countries (e.g., regions defined by river systems such as the Amazon, the Mekong and the Nile);

iv. Other areas of policy or analytical interest such as protected areas; areas owned by specific industries or sectors, e.g., government-owned land; or areas outside national jurisdiction, e.g., open oceans and high seas.[37]

3.27 Consistent with the scope in the SEEA Central Framework, the scope of national jurisdictions for ecosystem accounting should include all ecosystems across the terrestrial, freshwater and marine realms, to the boundary of the exclusive economic zone (EEZ). In practice, the initial scope may be more limited, for example covering only terrestrial and freshwater ecosystems; but it is important to aim to extend the coverage to incorporate all ecosystems under national jurisdiction.

3.28 Where countries share an administrative boundary, it will be most common for distinct EAA to be applied, one for each country. By delineating an EAA using an administrative boundary; this may also imply that a contiguous area of the same ecosystem type is partitioned between two or more countries. For the purposes of accounting within an individual EAA such partitioning is appropriate. However, in these contexts there may be advantages in (i) seeking alignment on the approach to defining and delineating the relevant ecosystem assets to ensure all areas are accounted for and are consistently classified; and (ii) considering the development of complementary accounts for transboundary areas that are of joint management interest. A particular case where this may be appropriate concerns large river basins and associated ecosystems.

3.29 Generally, the measurement objective of the SEEA EA is to provide information about the changes in ecosystem-related stocks and flows in relatively large and diverse areas encompassing different ecosystem types, as suggested by the examples of EAA above. Conceptually, it is possible to compile ecosystem accounts for an individual ecosystem asset such as a single forest, wetland or cultivated area but this is not the focus of the SEEA EA.

3.30 Usually, an EAA will reflect contiguous areas but this is not a requirement for accounting purposes. For example, accounts may be developed for all protected areas within a country or for a specific ecosystem type (e.g., for all natural grasslands in a country).

3.31 Within an EAA, multiple ecosystem assets will be grouped into different ecosystem types, e.g., forests, wetlands and cultivated land. The resulting accounting structures will generally be such that measures of ecosystem extent, ecosystem condition and ecosystem services will be presented for aggregations of ecosystem assets, i.e., by ecosystem types, based on data commonly compiled for ecosystem assets. For example, for a given EAA, an ecosystem extent account will show the changing total area of each ecosystem type (e.g., forest, wetland, coastal habitat or cultivated land) but will not present the changing area of each individual ecosystem asset. However, the same underlying data can be mapped to show the changing size, configuration and distribution of individual ecosystem assets within an EAA. Approaches to accounting for ecosystem extent are discussed in Chapter 4.

3.32 Since an EAA is a two-dimensional construct, the area of subterranean ecosystems cannot easily be incorporated alongside those ecosystem assets closer to the earth's surface. Therefore, for the purposes of accounting for ecosystem extent in which the area of the EAA and the sum of the areas of individual ecosystem assets should be equivalent, the area of subterranean ecosystems should be excluded. Where relevant for policy and analysis,

[37] These areas may be the focus of regional or international accounting work.

complementary extent accounts for subterranean ecosystems can be compiled (see section 4.3.3).

3.33 Complementary extent accounts for marine ecosystems beyond the continental shelf or EEZ that encompass the full range of relevant ecosystem assets, including those associated with pelagic ocean waters and deep-sea floors can also be compiled.

3.34 Where complementary extent accounts are compiled, other data concerning, for example, the condition of these ecosystem assets and the supply and use of ecosystem services, can be incorporated alongside similar data for other ecosystem types, at least in tabular form.

3.3 Delineating ecosystem assets

3.3.1 General principles

3.35 In concept, an ecosystem asset is differentiated from neighbouring ecosystem assets by the extent to which the interactions between biotic and abiotic components within the ecosystem asset are stronger than the interactions with components outside of the ecosystem asset. The differences will be reflected in variations in composition, structure and function. Hence, ecosystem assets should be delineated and classified to distinct ecosystem types, based on various ecosystem characteristics such as physical structure and type (including vegetation structure and type), species composition, ecological processes, climate, hydrology, soil characteristics, currents and topography.

3.36 It is expected that there will be a general persistence of the characteristics of an ecosystem asset allowing for a normal degree of natural variation. For example, the loss of vegetation as a result of disturbances such as fire and flood, will not necessarily imply a change in the ecosystem type. It is also expected that in the delineation of an ecosystem asset, the condition of that asset will be relatively homogenous following the approach to the measurement of ecosystem condition described in Chapter 5.

3.37 In delineating ecosystem assets for the purpose of ecosystem accounting, the following principles should apply.

i. *Ecosystem assets should represent ecosystems.* The spatial units should align with the definition of ecosystems following the CBD in which there is consideration of organisms, their environmental setting and ecosystem processes. It is accepted that the delineations cannot be perfect representations of the complex ecological reality.

ii. *Ecosystem assets should be capable of being mapped.* Ecosystem accounting is commonly implemented using a spatially-based approach, in which case it is necessary that ecosystem assets can be mapped and identified in a specific location.

iii. *Ecosystem assets should be geographically and conceptually exhaustive across ecological realms.* The 'exhaustive' criterion is understood as reflecting comprehensiveness, both spatially and conceptually, including built environments. The set of ecosystem assets should allow for an EAA to be fully tessellated, i.e., filled.

iv. *Ecosystem assets should be mutually exclusive, both conceptually and geographically.* Thus, EAs should not overlap, either conceptually or geographically, and any area on the land or the sea floor, or any horizontal depth layer in the ocean, should be occupied by one and only one ecosystem asset. As long as the ecosystem assets are mutually exclusive, there can be no double-counting of the same space. This principle is applied within a single dimension; i.e., within 1-D, 2-D or 3-D.

3.38 The occurrence and extent of ecosystem assets delineated using these principles can change over time. Indeed, the expectation is that over time, through the use of consistent principles and classifications, different boundaries would be delineated to reflect the changing sizes and configuration of ecosystem assets (e.g., due to expansion of urban areas or restoration of wetlands). Recording these changes, labelled in SEEA EA as ecosystem conversions, is the focus of accounting for ecosystem extent described in Chapter 4.

3.39 Where the boundary of an EAA, e.g., a country's national border, passes through a delineated ecosystem asset, only the area of the ecosystem asset inside the EAA boundary should be included in the account. While this effectively partitions the ecosystem asset, it ensures that the area of all ecosystem assets is equal to the total area of the EAA.

3.40 An EAA will contain a range of ecosystem types. In broad terms, a gradient exists from pristine natural areas to intensively managed ecosystems, including production plantation forests; croplands and meadows, and built environments. While natural areas are mainly governed by natural ecological processes, intensively managed areas will primarily (and semi-natural areas partly) be defined by land uses determined by human activity. However, since all of these types of areas may be within an EAA, all of these ecosystem types should be accounted for.

3.41 The composition of ecosystem types within an EAA will rarely be reflected in neat boundaries between easily identified areas of, for example, cultivated areas. In reality there will be a mixture of different features and ecosystem types throughout an EAA. In this context, two specific factors will influence the delineation in practice.

3.42 The first factor concerns the number of different ecosystem types for which delineation is undertaken. Thus, the greater the number of ecosystem types to be delineated, the more challenging the task but, at the same time, the greater the richness of the picture that will be able to be drawn and the more homogenous the ecosystem assets.

3.43 The second factor concerns the spatial scale at which delineation is undertaken. Thus, where delineation is undertaken at a low resolution, for example for 5km grid cells, it will be less likely that specific ecosystem assets, such as small wetlands, will be identified. On the other hand, where delineation is undertaken at high resolutions, for example for 30m grid cells, many distinct ecosystem assets may be identified.

3.44 In practice, a balance must be found between the resolution at which delineation is undertaken (and the related rules by which ecosystem types are identified) and the number of ecosystem types to be delineated. This balance will depend on data availability and analytical requirements. The general recommendation is that, for a given ecosystem account, a single spatial resolution of analysis should be selected and, consequently, an ecosystem asset will not be delineated unless it is sufficiently large in area such that it is identified at that resolution.

3.3.2 Approaches to identifying specific features

3.45 In addition to considering the number of ecosystem types and the resolution at which delineation is undertaken, it will also be necessary to assess whether there are specific features that need to be distinctly identified in the accounts. This section considers two particular cases in which specific guidance is appropriate: linear features and complex mosaics.

3.46 **Linear features:** In all EAA there are a variety of linear features. Typical examples are streams, rivers and road verges. If the resolution of delineation is sufficiently high, these features may be readily identified, but commonly they will be missed. For ecosystem accounting purposes, it is relevant to make a distinction between 'narrow' linear features, whose width is small enough to be treated as zero when accounting for the total area of an EAA (which must be equal to the sum of areas of individual ecosystem assets), and 'wide' linear features, whose width is large enough such that the associated area should be separately recorded.

3.47 The following treatments are recommended using the distinction between narrow and wide linear features and considering rivers and streams separately from other linear features.

i. For rivers and streams, width will change downstream along a river system, such that there will be a transition from 'narrow' upstream headwater reaches, to 'wide' downstream trunk rivers. Ideally, the area of sufficiently wide rivers and streams should be separately recorded. The treatment of this transition in the accounts will depend on the nature of the source data involved (e.g., between raster data, types of vector data). If delineating the area of rivers is not possible, they may be delineated in terms of length.

ii. For other linear features that are ecologically linked to surrounding landscape, such as ditches or hedgerows in a pasture landscape, it is recommended that they should not be separately identified and any associated area should be attributed to the ecosystem type of the surrounding ecosystem.

iii. For any linear features that are not ecologically linked to the surrounding landscape, such as forest access roads, the choice is to treat them like streams and rivers if sufficiently wide (i.e., as a distinct ecosystem type with an associated area), or to include them with the surrounding ecosystem types (i.e., without an associated area). This choice should be guided by the added value that a separate ecosystem type would have for the account or its applications.

3.48 These treatments are applied in the context of compiling a standard two dimensional extent account for an EAA. In some cases, there may be linear features that are of particular significance, economically, ecologically or culturally. To account for these features, it may be necessary to delineate ecosystem assets at higher resolutions such that the area of the relevant linear features can be separately identified alongside neighbouring ecosystem assets and so that the linear features can be separately accounted for, for example in terms of condition and ecosystem service flows. Further, in some instances there will be interest in a separate recording of linear features in terms of their length. A complementary set of one-dimensional extent accounts for such a purpose is described in Chapter 4.

3.49 It is noted that where a linear feature is attributed to the surrounding ecosystem, the condition of that ecosystem should take the presence of the linear feature into account. Thus, changes in the extent of linear features, e.g., increases in the kilometres of hedgerows, should be reflected in changes in the measure of condition. Incorporating linear features may have positive or negative effects on a measure of condition depending on the context.

3.50 **Complex mosaics**: Some spatial areas are characterised by a complex mix of different ecosystem types. Examples include urban areas and cultivated areas with small farm holdings. In concept, all of the different ecosystem types can be delineated following the general principles above provided the resolution is appropriately high. Then, in a second step, distinct EAA boundaries can be determined where there is interest in specific spatial areas, for example for urban areas and cultivated areas. This process supports a consistency in delineation across wider EAA, for example across a country, notwithstanding that some of the ecosystem assets delineated, such as green and blue spaces in urban areas, may be small relative to similar ecosystem types outside the complex mosaics.

3.51 Where there is interest in accounting for complex mosaics specifically, it will be relevant to apply complementary classifications of ecosystem types to support analysis and decision making (e.g., types of urban areas such as parks, lawns, ponds, etc; type of crops in cultivated areas). A discussion on the broader issues of delineation in accounting for urban areas, is presented in Chapter 13 on thematic accounting.

3.4 Classifying ecosystem assets

3.4.1 General principles

3.52 Ecosystem assets are classified into ecosystem types. Given the variety of ecosystem types and contexts around the world, there are many examples of ecosystem related classifications. For SEEA purposes, any ecosystem classification to be used for ecosystem accounting should ideally satisfy the definition of ecosystem types, i.e., representing a distinct set of abiotic and biotic components and their interactions, and enable application of the principles for delineating ecosystem assets listed in section 3.3.1.

3.53 Depending on the data available, compilation of accounts at national or sub-national level may involve the use of a large number of ecosystem types to ensure that accounts are suitable for the context. For the purpose of reporting and comparison among countries, a smaller number of higher-level classes is appropriate to facilitate use of the ecosystem data by a wide range of users.

3.54 It is recommended that existing national ecosystem classification schemes be used for ecosystem accounting wherever possible. Generally, such classification schemes will provide detailed descriptions and classes that incorporate specific local ecological knowledge. Cross-referencing of spatial units to the SEEA EA reference classification, the IUCN Global Ecosystem Typology (IUCN GET), will enable national level accounts to be scaled up and compared between countries (see section 3.4.2). Where specific national ecosystem types have been identified that do not translate directly to the SEEA EA reference classification, local ecological expertise should be applied to determine the most appropriate cross-referencing.

3.55 Where a national classification of ecosystems is not available, the IUCN GET may be used to develop one by scaling down to locally-derived and locally-relevant ecosystem types.

3.56 For the purposes of international reporting and comparison, the SEEA Ecosystem Type reference classification should be applied, reflecting the IUCN GET Ecosystem Functional Groups (EFG). Generally, this level of reporting will have fewer classes than ideal for national level account compilation and hence some aggregation of national classes will be required.

3.4.2 SEEA Ecosystem Type reference classification

3.57 The SEEA Ecosystem Type reference classification has been determined to ensure that compilation of ecosystem accounts in different locations can be compared against a commonly agreed set of ecosystem types which have been established on the basis of agreed principles. Since there are a variety of ways in which ecosystems can be classified and compilers are encouraged to use classes relevant to their local context, the availability of a reference classification provides a common baseline that can be used to evaluate the appropriateness of a given classification and to provide a structure for comparability of data and accounting methods.

3.58 The SEEA Ecosystem Type reference classification reflects the IUCN GET which was developed to support implementation of the IUCN Red List of Ecosystems. The IUCN GET is a global typological framework that applies an ecosystem process-based approach to ecosystem classification for all ecosystems around the world. In this approach, ecological assembly theory is used to identify key properties that distinguish functionally related ecosystems, and to synthesize traditionally disparate classification approaches across terrestrial, freshwater, subterranean and marine ecological realms. Using a focus on functionally related ecosystems at the higher levels of the classification allows similar but locally-different ecosystem types to be grouped in an ecologically meaningful way. This is particularly important for international comparison purposes where the variety of ecosystem types is very large.

3.59 The IUCN GET has a structure consisting of six levels. The three upper levels (levels 1-3) differentiate the functional properties of ecosystems, while IUCN GET Levels 4-6 correspond to finer levels of detail on ecosystem types that will be relevant in national and sub-national contexts. It would be expected that existing national ecosystem type classes would be described at a level of detail corresponding conceptually to IUCN GET level 5 or 6. D. A. Keith et al. (2020) provide a full description of the IUCN GET and its approach to classification.

3.60 The SEEA Ecosystem Type reference classification is equivalent to IUCN GET Levels 1-3. The focus on these levels allows (i) national variations in the description of local ecosystem types to be developed recognising the importance of locally-relevant classes; and (ii) ecologically meaningful groupings of locally-relevant ecosystem types to be formed for the purposes of integrating national-level data from different sources (e.g., agriculture, environment, forestry, and marine data).

3.61 The top level defines four realms: marine (M); freshwaters and saline wetlands (F); terrestrial (T); and subterranean (S). A realm is a major component of the biosphere that differs fundamentally in ecosystem organization and function. The subterranean realm is included in the reference classification noting that for a standard two dimensional extent account these ecosystem types will be out of scope. The top level also provides for the classification of atmospheric units to an atmospheric realm at a future date which would provide complete coverage of the biosphere. As noted in section 3.2.1, that part of the atmosphere above the atmospheric boundary layer is not included in the scope of ecosystem assets.

3.62 The second level of the classification broadly follows the modern functional biome concept in which a biome is *"a biotic community finding its expression at large geographic scales, shaped by climatic factors and characterized by physiognomy and functional aspects, rather than by species or life-form composition"* (Mucina, 2019). The IUCN GET defines 24 biomes: four exclusively in the marine realm; three exclusively in the freshwater realm; seven exclusively in the terrestrial realm; four exclusively in the subterranean realm; and six that are located in transitional areas between different realms. These transitional areas represent interfaces between various combinations of the marine, freshwater, subterranean and terrestrial realms.

3.63 Levels 1 and 2 of the SEEA Ecosystem Type reference classification are shown in Table 3.2. Many of the ecosystem types described at Level 2 are familiar as naturally occurring biomes, including tropical forests, shrublands, deserts, freshwater lakes and pelagic ocean waters. Six biomes are defined by anthropogenic processes,[38] where human activity is pivotal to ecosystem assembly and maintenance of ecosystem components and processes.

3.64 The third level of the classification describes ecosystem functional groups (EFG). ***EFG are functionally distinctive groups of ecosystems within a biome*** and are defined in a manner consistent with the CBD definition of ecosystems which underpins the SEEA EA concept of ecosystem assets. Ecosystem types within the same EFG share common ecological drivers which promote convergence of the biotic traits that characterize the group. There are 98 EFGs in the IUCN GET though it would be highly unlikely for a country to have ecosystem assets

[38] Also referred to as "anthromes" - see Ellis (2011); Ellis et al. (2010).

representative of all EFG. More commonly, less than 40 EFG would be present in a single EAA. A full listing of the EFG classes is provided in Annex 3.2.

3.65 For the compilation of ecosystem accounts at national or sub-national level it is expected that the delineation of ecosystem types would occur at fine levels of detail using national classifications. The compilation of ecosystem accounts may occur at this same level of classification. For the presentation of ecosystem accounting outputs, either in tabular or map format, it may be appropriate to combine fine level classes. For example, presentation may occur at the equivalent of the EFG level. It is expected that for the purposes of international comparison, the reporting of data at the EFG level (level 3) would be appropriate.

3.66 Specific mention is made of the six anthropogenic biomes: T7 (Intensive land use), which includes croplands, pastures, plantations and urban areas, F3 (Artificial wetlands), M4 (Anthropogenic marine ecosystems), S2 (Anthropogenic subterranean voids), MT3 (Anthropogenic shorelines) and SF2 (Anthropogenic subterranean freshwaters), and their composite EFGs. For a range of ecosystem accounting purposes, there will be interest in accounting at a finer level of detail than the EFGs that are within these biomes. For example, urban ecosystems (T7.4) are often structurally complex and highly heterogeneous; and annual croplands (T7.1) consist of fields of varying crop types and fallow land. To delineate and report on spatial units within the above mentioned anthropogenic biomes and their corresponding EFGs, various ecosystem sub-types may be identified. It is recommended that national land use classes be used to define these, or, as needed, the classes of the SEEA Central Framework Land Use Classification (at the 3-digit level).

Table 3.2: SEEA Ecosystem Type Reference Classification based on the IUCN GET

Realms	**Biomes**
Terrestrial	T1 Tropical–subtropical forests
	T2 Temperate–boreal forests & woodlands
	T3 Shrublands & shrubby woodlands
	T4 Savannas and grasslands
	T5 Deserts and semi-deserts
	T6 Polar-alpine
	T7 Intensive land-use systems
Freshwater	F1 Rivers and streams
	F2 Lakes
	F3 Artificial fresh waters
Marine	M1 Marine shelfs
	M2 Pelagic ocean waters
	M3 Deep sea floors
	M4 Anthropogenic marine systems
Subterranean	S1 Subterranean lithic
	S2 Anthropogenic subterranean voids
Transitional	TF1 Palustrine wetlands
	FM1 Semi-confined transitional waters
	MT1 Shoreline systems
	MT2 Supralittoral coastal systems
	MT3 Anthropogenic shorelines
	MFT1 Brackish tidal systems
	SF1 Subterranean freshwaters
	SF2 Anthropogenic subterranean freshwaters
	SM1 Subterranean tidal

Source: D. A. Keith et al. (2020).

3.67 The use of the IUCN GET as the reference classification of ecosystem types reflects the need for a globally applicable classification of ecosystem types covering all realms. There are a range of existing global classifications of ecosystem types, habitats, land cover and land use; and also regional or realm specific classifications of ecosystem types that may be used in other contexts. Examples include classes present in the World Terrestrial Ecosystems for terrestrial areas (Sayre et al., 2020); in the European Nature Information System (EUNIS) and Mapping and Assessment of Ecosystem Services (MAES); in the FAO Global Agro-Ecological Zones; SEEA Land cover and Land use classifications; in the Moderate Resolution Imaging Spectroradiometer (MODIS) classes; and in the global convention reporting classes such as those concerning the UNFCCC and the Ramsar Convention on Wetlands. To support the integration of data and the compilation of accounts correspondences among these classifications will be developed building on, for example, Bordt & Saner (2019) and UNCCD (2017).

3.5 Considerations in the delineation of spatial units

3.5.1 Delineation of ecosystem assets in practice

3.68 The distinction between ecosystem assets of different types is ecological. This reflects an understanding of the differing composition, structure and function of the various biotic and abiotic components and their interactions. In principle then, delineating the boundaries between ecosystem assets is statistically observable and can be undertaken through comprehensive and regular assessments by ecologists on the ground, including assessments of changes over time.

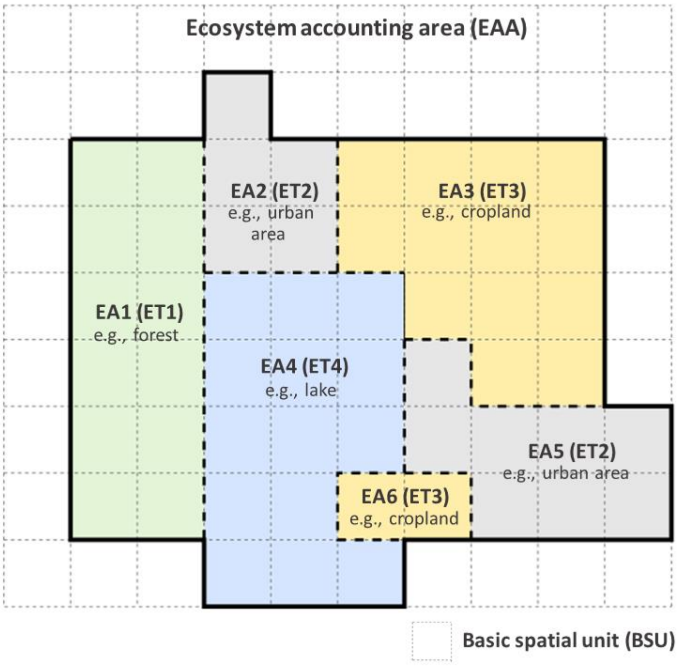
3.69 In practice, the high resource costs involved in ground assessments mean that the delineation of ecosystem assets will likely involve the mapping of different ecosystem types within an EAA using remote sensing data from satellites where possible. At the same time, it will be necessary to develop regular programmes of ground assessments to support the calibration of remote sensing data.

3.70 Irrespective of the data collection approach, the data should be collated and analysed by applying geographic information systems (GIS) platforms and techniques. This will have the benefits of supporting the integration and manipulation of spatial data from various sources and providing the potential to reliably and sustainably organise and compare the data. This work is specialised but there is extensive practical and theoretical understanding of the use of GIS to support the delineation of ecosystem assets for ecosystem accounting purposes. The use of GIS platforms and techniques will be relevant in other areas of ecosystem accounting. Accompanying technical guidance on the use of GIS techniques and tools for ecosystem accounting is being developed in the *Guidelines on Biophysical Modelling for Ecosystem Accounting* (UNSD, n.d.-a, forthcoming).

3.71 While the use of GIS is standard, it will be necessary to involve ecological expertise to assure that the boundaries drawn between ecosystem assets are appropriate in ecological terms with regard to the ecosystem type classification that is adopted and that the changes through time are meaningful. In addition, where ground assessments are carried out this information should be integrated appropriately to provide the most accurate measures or used as part of data validation work.

3.72 To operationalise the delineation of EA within GIS systems, it may be appropriate to use a basic spatial unit (BSU). ***A BSU is a geometrical construct representing a small spatial area.*** The purpose of BSUs is to provide a fine-level data framework within which data about a range of characteristics can be incorporated. An example of a BSU is a grid cell, but other BSU shapes, for example reflecting polygons, may be used. Figure 3.4 shows how a grid-based BSU can be overlaid on an EAA to assist in delineating the ecosystem assets included in the earlier example (shown in Figure 3.3).

Figure 3.4: Applying a grid based BSU to delineate EA



3.73 To apply a BSU technique, each BSU is attributed with data on characteristics that are relevant in distinguishing between ecosystem assets of different types. One way of envisaging this is that over the entire EAA data about each characteristic is mapped at the BSU level to establish a data layer for that characteristic.

3.74 As noted, different ecosystem types will be distinguished through combinations of a number of characteristics. At a basic level it is necessary to combine data on land cover, climate (e.g., temperature regime, precipitation regime, potential evapotranspiration) and landforms (e.g., soil type, lithography, geomorphology). From this starting point, a range of other characteristics may be added, for example concerning water, carbon, nutrients, etc.

3.75 The extent to which it is possible to combine multiple data sets to delineate ecosystem assets will depend on data availability. Where available, existing maps that delineate ecosystem assets may be used. As a second option, ecosystem asset maps may be generated using national level information on land cover, climate, landforms and other characteristics as relevant following the descriptions above.

3.76 Where national level data on basic characteristics are not available, global datasets may be used. This approach has been applied in a number of contexts. An example is the map of terrestrial World Terrestrial Ecosystems (WTE) (Sayre et al., 2020), which was derived from the objective development and integration of global temperature domains, global moisture domains, global landforms, and 2015 global vegetation and land use data. As a final option, it may be necessary to use data on the single characteristic of land cover to provide an initial delineation of ecosystem assets.

3.77 For those biomes that are subject to direct human management (particularly Biome T7: Intensive land-use, including croplands and plantations), it will be appropriate to incorporate data on land and ecosystem use in the delineation of ecosystem assets in addition to data on other variables such as land cover. In this context, land and ecosystem use data can provide an indicator of differing ecological composition, structure and function. The potential to identify separate ecosystem assets within these biomes is discussed in section 3.4.2.

3.78 While the focus of the description here is on the use of spatial approaches to delineating ecosystem assets, data on the extent of ecosystem assets, or of specific ecosystem types, may be collected via other means, for example, using surveys of land holders. For certain ecosystem types, for example cultivated areas and forests, the collection of data in this way will provide input to the accounts. However, data in this form will not support the derivation of maps since the precise location and boundaries of the ecosystem assets will not be recorded. Consequently, alignment with data on other ecosystem types may also be challenging and the risks of double counting or missing areas of ecosystems are increased. However, non-spatial data may be valuable to support data quality assurance and estimation of ecosystem condition and ecosystem services.

3.5.2 The use of data on the characteristics of land

3.79 In ecosystem accounting there is commonly an interest in accounting for terrestrial ecosystems and hence the use of data associated with the various characteristics of land is of immediate relevance and interest. One reason for this interest are demonstrated rapid and significant changes in terrestrial ecosystems, for example due to urban and agricultural expansion. As described above, while land cover and land use data are not sufficient to delineate ecosystem assets, they provide much relevant information for the measurement of ecosystem extent for terrestrial ecosystem types. These data may also be of direct use in the measurement of ecosystem service flows and in the monetary valuation of ecosystem services and ecosystem assets.

3.80 Both land cover and land use data should be organised following the concepts and definitions outlined in the SEEA Central Framework. Land cover refers to the observed physical and biological cover of the Earth's surface and includes natural vegetation and abiotic (non-living) surfaces. At its most basic level, it comprises all of the individual features that cover the area within a country. For the purposes of land cover statistics, the relevant country area includes only land and inland waters.

3.81 There are several international land cover classifications that may be used, providing well documented and tested metadata. The standard classification of land cover in the SEEA Central Framework is based on the FAO Land Cover Classification System (LCCS).[39]

3.82 Land use reflects both (a) the activities undertaken and (b) the institutional arrangements put in place for a given area for the purposes of economic production, or the maintenance and restoration of environmental functions. In effect, "use" of an area implies the existence of some human intervention or management. Land in use therefore includes areas, for example, protected areas, which are under the active management of institutional units of a country for the primary purpose of conserving biodiversity and other environmental values (SEEA Central Framework, para. 5.246).

3.83 Land management is the process of managing the use and development of land resources. The degree that areas of land and water are managed by humans may differ from more intensively managed (e.g., build up areas, cropland) to less intensively managed (e.g., polar regions, oceans). The degree of land management can have positive or negative effects on ecosystems and monitoring changes in the degree of management may be of interest in monitoring the links between changes in ecosystem assets, their condition and land management policies and decisions.

[39] For the FAO Land Cover Classification System (LCCS) see http://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/en/c/1036361/

3.84 Land ownership is a key characteristic that provides a direct link between ecosystems, their management and economic statistics. Economic assets, including land, can be assigned and classified to institutional units (i.e., corporations, government, households, non-profit organizations) based on ownership. Not all ecosystems are owned, namely some remote natural areas or the oceans (e.g., the high seas beyond the EEZ) and hence various accounting conventions are established. Also, in many countries there are communally owned areas, for example, areas used for the rearing of livestock. Relevant conventions for the allocation of ownership are discussed in Chapter 11 in the context of integrating ecosystem accounts with the SNA sequence of accounts. Data on land ownership for terrestrial ecosystems is available in many countries in the form of cadastres. Cadastres are registers of areas defined administratively and delineated on the basis of ownership.

3.85 The data on each of these characteristics of land – cover, use, management and ownership – can be overlaid (where spatial data are available) or presented in conjunction with data on the extent of ecosystem assets and associated measures of condition and ecosystem services. Thus, for example, data from cadastres showing the sector of ownership or the nature of the tenure can be linked to data on ecosystem assets, and hence provide a basis for monitoring the effects of land management policies within a given region, e.g., a water catchment.

3.5.3 Organising data about socio-economic and other characteristics

3.86 Beyond land related data, the delineation of ecosystem assets will generally require the use of various data concerning several ecosystem characteristics as noted above. The organisation of these data may create the opportunity to establish a richer data base of spatial information. This would include data on land management and ownership described above and also data on, for example, the stocks and flows of water and carbon; the presence of particular species (either endemic or invasive); measures of soil and water quality; temperature, slope and elevation; pollution and other residual flows; the production of agricultural, forestry and fisheries outputs; and indicators of recreational activities and cultural sites.

3.87 A motivation for organising these additional data emerges from ecosystem accounting since while data on only certain characteristics are required for the delineation of ecosystem assets, there are many other characteristics that will be relevant for accounting for ecosystem condition, estimating flows of ecosystem services and determining monetary values for ecosystem services and ecosystem assets. Data concerning ecosystem extent, condition and services may be further enriched by the integration of spatially detailed socio-economic data, for example demographic data.

3.88 Particular note is made concerning the measurement of ecosystem services where both the supply and the use of ecosystem services must be recorded. In some cases, e.g., biomass provisioning services, the location of the supply and the use of the services is the same and occurs in a single ecosystem asset. In other cases, e.g., air filtration services, the supply of the service may take place in a different location from the use; and in other cases, e.g., flood mitigation services, it is necessary to allocate the supply of the service to a combination of ecosystem assets. Spatial attribution of the supply and use of ecosystem services is therefore an important task to ensure appropriate recognition of the role of different ecosystems and the mix of different users. These issues are discussed further in Chapter 7.

3.89 Spatial data concerning additional characteristics should be attributed to ecosystem assets to support coherence in accounting terms. Operationally, this attribution may be applied using a BSU based structure to align and integrate spatial data on different characteristics and hence account for the varying spatial coverage, scales and projections. Since the extent and configuration of ecosystem assets will change over time, the nature of the attribution of data will also change. Thus, use of an agreed BSU structure, or master layer, will likely provide considerable computational advantages.

3.90 Ideally, it is envisaged that a country would use the principles of the Integrated Geospatial Information Framework[40] to underpin the collation and organisation of spatial data, which in turn could provide a coherent "one-map" for a country, including its marine ecosystems, across many ecological, social and economic characteristics. Countries are therefore encouraged to use the implementation of ecosystem accounting as an opportunity to integrate spatial data and techniques.

[40] See https://ggim.un.org/igif.

Annex 3.1: Ecological concepts underpinning spatial units for ecosystem accounting

Introduction

A3.1 This annex provides a short introduction to ecological concepts such that compilers of accounts with a non-ecological background can gain an appreciation of some of the complexities in delineating and measuring ecosystem assets. The discussion should also support a more informed discussion with experts in ecology by providing a basic framework for ecological concepts and a summary of key ecosystem characteristics.

Key ecological concepts

A3.2 A range of related but different characteristics of areas are used in ecology, each reflecting different ecological concepts. This section summarizes the key concepts of relevance in the context of ecosystem accounting.

Ecosystems

A3.3 The central concept of interest for ecosystem accounting and classification is that of the ecosystem itself. The most important element of this definition is the final clause "interacting as a functional unit", which means that the abiotic environment (climate, lithology, hydrology, etc.) is not relevant on its own, but in relation to biota (if only in a one-directional way), from an ecosystem functioning point of view. Ecosystem function refers to the processes related to the fluxes of resources like energy and water, photosynthesis and decomposition, that make up the interactions between the ecosystem components (Agren & Andersson, 2011).

A3.4 D. A. Keith et al. (2020), building upon assembly theory (i.e., the selection of ecological communities through environmental filtering of available trait/species pool (Keddy, 1992)), distinguish five groups of processes that govern ecosystem functioning.

- **Resources** (energy, nutrients, water, carbon, oxygen etc.). One or more of these will often be limited, inducing an ecosystem functional response such as competition;
- **Ambient environmental conditions** (temperature, salinity, geomorphology etc.). These factors regulate the availability of, and access to resources, as well as ecological processes (temperature controls biochemical reaction kinetics, geomorphology controls soil moisture conditions, etc.);
- **Disturbance regimes** (fire, floods, mass movements etc.). These factors episodically destroy existing ecosystem structures and/or introduce or release new resources and niches;
- **Biotic interactions** (competition, predation, ecosystem engineering etc.). These are largely endogenous processes that shape ecosystem structure and function, but they include organisms that act as mobile links connecting different ecosystems and regulating transfers of matter and energy between them; and
- **Human activity.** Anthropogenic processes are a special kind of biotic interaction that influence structure and function of ecosystems either directly (e.g., land cover change, movement of biota) or indirectly (e.g., the harvest of biomass and other forms of resource use, climate change).

A3.5 Together, these processes and conditions give rise to a variety of ecosystem traits, such as productivity, diversity, trophic structure, physiognomy, life forms and phenology. The assembly processes and ecosystem traits both influence stocks of assets and flows of services by shaping ecosystem structure and function. The same processes that determine the 'identity' of an ecosystem also determine their integrity. Accordingly, variables that describe these processes and characterize the state of an ecosystem with respect to them will also be in the focus of ecosystem condition accounts (chapter 5).

Habitat and biotope

A3.6 The concept of habitat is closely related, but not identical to ecosystems. It is defined as "a location (area) in which a particular organism is able to conduct activities which contribute to survival and/ or reproduction" (Stamps, 2008). It thus is organism-specific, focuses on both biotic and abiotic factors, and has a geographical component. Thus, habitats are provided by ecosystems for individual species. For example, a closed cover of Larix trees may define a taiga forest ecosystem which provides a habitat for woodpeckers.

A3.7 The term biotope is often used interchangeably with habitat, but is often assigned to the community concept, and habitat to the species concept. Thus, a species has a certain habitat, but the group of species that share an ecosystem with that species in a geographic region, share a biotope (Dimitrakopoulos & Troumbis, 2019). A biotope is a topographic unit, and can be considered to be equivalent with Ecosystem Asset.

Realms

A3.8 A realm is a major component of the biosphere that differs fundamentally in ecosystem organization and function. The four core realms are Terrestrial, Freshwater, Marine and Subterranean. Each realm consists of different biomes (see next section). There are also a number of transitional realms relating to ecosystems that are found between the core realms – for example the marine-terrestrial realm which contains shoreline and coastal ecosystems.

Biome

A3.9 A biome is *"…a biotic community finding its expression at large geographic scales, shaped by climatic factors, and perhaps better characterized by physiognomy and functional aspects [of vegetation], rather than by species or life-form composition. Biomes are frequently used as tools to provide large-scale (regional to global)* backgrounds *in a range of ecological and biogeographical studies."* (Mucina, 2019). Biomes are the largest geographical biotic communities that are convenient to recognize. Most of them broadly correspond with climatic regions (zonobiomes), although other environmental controls are sometimes important, e.g., soils (pedobiomes) or topography (orobiomes).

A3.10 There is no single authoritative list of biomes. While some biomes are recognized by all authors (e.g., tropical rainforest, taiga) many different biomes are proposed for less well-defined ecosystems, especially those on ecotones, such as savannas and woodland. For SEEA purposes, the IUCN GET list of biomes is used as a reference.

Ecoregions

A3.11 An ecoregion is "A geographic group of landscape mosaics," "resulting from large-scale predictable patterns of solar radiation and moisture, which in turn, affect the kinds of local ecosystems and animals and plants found there (Bailey, 2009, 2014). Individual ecosystems (i.e., ecosystem assets) within an ecoregion may have a strong functional relationship with each other, e.g., where upstream ecosystems regulate water and nutrient resources for downstream ecosystems, or they may be functionally unconnected, e.g., when two ecosystem assets of the same ecosystem type, but in adjacent sub-catchments, simply reflect the same abiotic conditions as soil, climate and topography. Ecoregions are often used within a mapping context, and are described with a hierarchical structure. Terrestrial ecoregions are often grouped into higher order biogeographic regions, where the different biogeographic regions (e.g., Nearctic for North America, Indomalaya for India and South-East Asia, etc.) reflect global differences in species distributions due to geographic separation and evolutionary history. On a smaller scale, ecoregions may be spatially contiguous units of a single biome, or subdivisions thereof, e.g., “West Siberian Taiga” and “East Siberian Taiga” (Olson et al., 2001).

Ecotones

A3.12 Ecotones are places where ecosystems grade into each other along a gradient in one or more resources or environmental controls. A typical example is the transition from forest to grassland on a gradient of moisture availability. The precise location of ecosystem types, and hence the ecotones between them is ultimately subjective. Where these gradients are very gentle, ecotones can occupy quite extensive areas. The translation of gradients and ecotones on ecosystem classification will depend on the nature and ‘sharpness’ of the transition, and the scale of application.

Key characteristics of ecosystems

A3.13 In each of the three core environmental realms - terrestrial, freshwater, and marine - ecosystems are commonly understood as occupying space and comprising an abiotic complex, a biotic complex, and interactions between the two. This section describes the key characteristics of terrestrial, freshwater and marine ecosystems. These characteristics are linked to ecosystem structure and functioning and play a key role in classifying ecosystems within each realm, as well as in measuring their condition. In line with the intention of this annex, this section does not provide an exhaustive listing of ecosystem characteristics and is intended primarily to convey some level of the richness of ecosystems that should be considered in their delineation and measurement.

Terrestrial ecosystems

A3.14 Terrestrial ecosystems occur on land and are limited by the presence and availability of water and nutrients. The key drivers that lead to the presence of different ecosystem types are climate, topography and geomorphology, lithology and human activities. In summary:

- **Climate**, pragmatically defined as the statistics of weather, is an important driver of many ecosystems, because of its strong links to resources (e.g., water, energy) and constraints (e.g., droughts). From an ecological point of view the most relevant climatic parameters are (i) temperature (mean annual temperature; seasonality; temperature of the coldest month; accumulated growing degree-days); (ii) precipitation (total annual precipitation; seasonality); and (iii) potential evapotranspiration (annual total; seasonality);
- **Topography and geomorphology** affects the climate (on the global and local scale), moisture conditions (on the regional and local scale), and nutrient redistribution. Examples of different topography and geomorphology include (i) hillslopes and plains (hillslopes have improved drainage compared to plains); (ii) gentle and steep slopes (steeper slopes will have more shallow soils, faster drainage and possible more disturbance due to mass movements); (iii) low and high topography (adiabatic expansion of rising air causes cooler and wetter (micro) climate on high plains and mountains); and (iv) profile and planform convexity (topographic controls on hillslope hydrology promote relative dry conditions on convex divergent hillslopes, and relatively wet conditions on concave hollows and the convergent channel network);
- **Lithology** determines the parent material for soil formation, and, as such, controls vegetation primarily through resource processes (especially nutrient availability),

through mineral composition and through weathering products, such as the formation of clay minerals; and

- **Human activities** that impact on ecosystems can be either direct (e.g., land cover change, movement of biota) or indirect (e.g., resource use, climate change).

A3.15 The key characteristics of terrestrial ecosystems are shaped by these drivers. The distribution, composition and significance of these characteristics will vary significantly, for example, from tropical rainforests to alpine ecosystems. Key abiotic characteristics of terrestrial ecosystems are soil and moisture regime. Key biotic characteristics include vegetation, animals and biota (such as fungi and bacteria). Collectively, the biotic characteristics are reflected in variations in the structure, composition and function of ecosystems.

A3.16 Concerning key characteristics of soil and vegetation the following points are relevant:

- **Soil**, which controls vegetation primarily through a number of resource processes, and is formed partially by the local current and past ecosystem processes. Relevant soil characteristics include:
  - Soil chemical properties such as Cation Exchange Capacity (CEC) which determine the capacity of the soil to retain nutrients;
  - Soil physical properties, such as texture, porosity, drainage, permeability, among others, which determine the characteristics and availability of moisture during dry periods; and
  - Soil organic matter, which is an important biota-controlled soil characteristic that contributes to the chemical and physical properties just noted.
- **Vegetation**, which may be used as a proxy for all biota. The terms vegetation and ecosystems are often used interchangeably (e.g., Tropical Rainforest), but vegetation is rather a biotic element of an ecosystem and exists in a physical environmental context which defines it. For many ecosystems, and for terrestrial ecosystems in particular, vegetation is an important element of the classification and labelling process. Vegetation is generally characterized by species assemblages which have a strong spatial expression and whose occurrences are therefore recognizable on the landscape. Vegetation can also be characterized by a set of more generic plant functional traits, e.g., Pérez-Harguindeguy et al. (2013), including:
  - Growth form, e.g., trees, shrubs, grass etc. and the corresponding canopy architecture;
  - Raunkiær life-form, e.g., Phanerophytes (woody, buds >25 cm above the ground) and geophytes (buds in dry ground);
  - Life history, e.g., annuals vs perennials;
  - Leaf type and phenology, e.g., broadleaved, needle-leaved, deciduous, evergreen; and
  - Adaptations to moisture stress (xerophytes) or salt stress (halophytes).

Freshwater ecosystems and wetlands

A3.17 Freshwater ecosystems are characterized by the presence of surface waters whose surface extent can vary spatially over time, and whose vegetation consists of largely aquatic species.

The main distinction among freshwater ecosystems is between flowing water systems (e.g., rivers and streams) and low- or non-flowing systems (e.g., lakes, ponds, and wetlands). Many of the drivers and characteristics are correlated with each other, and vary quite predictably along a downstream gradient.

A3.18 The key drivers and abiotic characteristics of rivers and streams include:

- **Morphology.** By definition, rivers and streams are geomorphological features and can be distinguished in terms of (i) stream order, i.e., the position from source (lowest order) to outlet (highest order), as a proxy for and classification of, drainage area; (ii) fluvial zone (erosional; transfer; depositional); (iii) sediment size (bedrock; boulders; gravel; sand; clay) and mobility (bedload, suspended); (iv) channel pattern[41] (straight; meandering; wandering; braided; anastomosing); and (v) bedform (planar; ripples; pool-riffle; bars);
- **Hydrology** which can be ephemeral, intermittent, perennial or interrupted; and
- **Chemistry** involving, for example, oxygen and nutrient concentration.

A3.19 The key drivers and abiotic characteristics of **lakes and pools** include:

- **Origin**: e.g., tectonic, volcanic, glacial, karstic, fluvial, artificial;
- **Stratification**: e.g., meromictic (never mixes), monomictic (mixes once a year), dimictic (twice a year) and polymictic (often mixed);
- **Trophic status**: oligotrophic (nutrient-poor) and eutrophic (nutrient-rich);
- **Salinity**: freshwater lakes and salt lakes; and
- **Permanency**: e.g., episodic, seasonal and permanent lakes.

A3.20 The key biotic characteristics for rivers, streams, lakes and pools include fish; macroinvertebrates and vegetation.

A3.21 **Wetlands** can be broadly defined as ecosystems that arise when inundation by water produces soils dominated by anaerobic processes, which, in turn, forces the biota, particularly rooted plants, to adapt to flooding (Keddy, 2010).

A3.22 Some key drivers and abiotic characteristics of wetlands are:

- **Morphology**: terrain-conforming vs self-emergent;
- **Hydrological system**: permanence/seasonality of water levels (water availability), minerotrophic (groundwater, surface) vs ombrotrophic (precipitation);
- **Trophic status**: oligotrophic (nutrient-poor) vs eutrophic (nutrient-rich); and
- **Landscape position**: along streams(riverine), lakes (lacustrine), estuarine or disconnected/upstream (palustrine).

A3.23 The key biotic characteristics of wetlands concern the **dominant vegetation type**. This may be bryophytes and graminoids (bog and fen or peatland), graminoids, shrubs, forbs or emergent plants (marsh) or trees, shrubs and forbs (swamp), submerged of floating aquatic plants (shallow water).

[41] Note that channel pattern is strongly controlled by bank strength, which itself is partly controlled by vegetation. On longer time scales channel pattern can thus be regarded as an ecosystem characteristic, rather than a driver

A3.24 As for terrestrial ecosystems, human activities can be a significant driver of freshwater and wetland ecosystems for example through the fragmentation of river systems with dams and the draining of wetlands.

Marine ecosystems

A3.25 Marine ecosystems consist of all salt-water ecosystems that are directly connected to the world's oceans. From a broader ocean perspective, this also includes coastal transitional and intertidal ecosystems (estuaries, deltas, coastal salt marshes and other shorelines).

A3.26 **Bathymetry** is the marine equivalent to topography for terrestrial ecosystems. It is a measure of the depths and shapes of the marine environment when looking at the transition from coastal landscapes to the deeper open ocean environment. In considering this transition, **benthic** refers to those habitats or organisms associated with the ocean floor as it extends from the shoreline to increasing depths, while **pelagic** refers to habitats or organisms existing in the marine water column.

A3.27 The key drivers of marine ecosystems are:

- **Bathymetry** influences the characteristics of marine ecosystems since the depth profile will determine exposure of the underlying water layer and/or ocean bottom to air/wind, precipitation, currents, light, and nutrients. Bathymetry is considered in two primary ways. First, **intertidal or littoral zones** create different requirements for biota using these areas compared to **open ocean zones**. For example, the intertidal zone is affected by tides and is above water for part of the day, so biota living within this area will need to have strategies to adapt to potential exposure to air and precipitation. Second, **photic** (with light)**, disphotic** (insufficient light for photosynthesis)**, and aphotic** (no light) **zones** are designated based on the ability of light to penetrate to the deeper parts of the water column, which limits photosynthesis. For example, the continental shelf is relatively shallow and its photic zone is home to light-dependent ecosystems such as corals, seagrasses and kelp, the continental margin begins the slope to deeper aphotic ecosystems on the abyssal plain where virtually no light penetrates;

- **Climate** affects and is affected by the ocean. There are four key aspects to consider. First, **wind** generates surface currents and waves that support the ocean circulation system that moves water, nutrients, and biota globally. The strength of surface winds also plays an important role in the depth of the mixed layer and in upwelling of nutrient-rich deeper waters in coastal locations. Second, the **pH** (acidity) of the oceans, which currently averages on the somewhat basic or alkaline side of the pH scale (approximately 8), determines the types of biota that can survive in the marine ecosystem. Decreases of pH because of increased atmospheric carbon dioxide, also known as ocean acidification, can negatively impact certain biota, such as corals and shellfish. Third, the **temperature** of the oceans will depend on atmospheric warming, and water temperature will determine the ability of aquatic biota to tolerate certain coastal and marine environments. This can result in changes in the distribution of marine biota. Changing global air temperatures can also impact the ocean ecosystem through inputs of freshwater from melting glaciers. Fourth, **precipitation** impacts the flow of freshwater into coastal and marine systems, thereby influencing the salinity and density of water layers;

- **Lithology** (underlying rock material) determines the substrate present on the ocean floor or sea bottom. This can consist of a variety of materials of various origins, e.g., rocky, sand, mud, biogenic (corals, oyster/mussel beds) that shape marine ecosystems;
- **Ocean circulation** patterns bring warmer water to cooler continents and vice versa, regulating the temperatures observed in different parts of the globe. The Earth's climatic zones of arctic, temperate, tropical and Antarctic are very much affected by these ocean processes. **Currents and thermohaline circulation** (which moves surface waters deep into the ocean) also move nutrients and oxygen globally, shaping coastal and marine ecosystems. Equatorial currents moving in opposite directions (clockwise north of the equator and counter-clockwise south of the equator) create productive areas with upwelling of nutrient-rich deeper waters. The intersection of deep ocean circulation with bathymetry, as occurs when nutrient-rich currents meet seamounts, creates highly productive upwelling areas for marine biota;
- **Salinity** differences between estuarine (mix of salt and freshwater) versus open ocean (saltwater) environments determines the biota that thrive in these settings;
- **Stratification** of coastal and marine water layers based on temperature, salinity, and density, as well as factors such as surface winds, plays an important role in driving marine ecosystem structure and function. Stratification will vary seasonally and by location on the globe. The **surface mixed layer** is the area of greatest turbulence and circulation of water because of its proximity to surface winds, which results in relatively uniform temperature and salinity. As a result of temperature and salinity differences between the surface and deeper waters, density differences create a boundary between these relatively nutrient poor waters at the surface and relatively nutrient rich deeper waters; and
- **Human activities** impact on marine ecosystems having both direct and indirect effects. Direct effects include harvesting marine species, ecosystem modification, noise and release of nutrients, litter and invasive species into marine and coastal waters. Indirect effects include impacts on climate that then drive changes in the marine ecosystem characteristics.

A3.28 The key abiotic and biotic characteristics are:

- **Biota:** Biota in the sea column (pelagic biota) may actively propel themselves through the water (nekton: including some bacteria, algae, invertebrates, fishes, birds and mammals) or passively be carried by the currents and winds (plankton). Biota associated with the sea floor (benthic biota) can consist of complex three-dimensional structures formed by sessile (stationary) suspension feeders such as aphotic coral, sponges and bivalves, plants such as seagrasses and kelp, invertebrates and bacteria;
- **Sediment chemical and physical properties** can indicate the potential for sediments to support biota and associated biological and chemical processes as well as their status as a carbon sink;
- **Water column** characteristics are important in evaluating the condition of the marine ecosystem. Relevant characteristics concern (i) water temperature which influences the suitability of a marine ecosystem as habitat for biota; and (ii) water quality which

is influenced by natural and anthropogenic inputs and processes, including contaminants, nutrients, litter (including plastics) and sediment and freshwater inputs from land. These inputs, as well as broader climatic drivers, can impact dissolved oxygen, salinity, and turbidity (cloudiness) as well as the health of marine biota in the system. Water quality can be an important marker of marine ecosystem condition; for example, low dissolved oxygen levels may indicate an ecosystem impacted by excess anthropogenic nutrient inputs; and

- **Vegetation:** Coastal and marine vegetation, including mangroves, seagrasses, and seaweeds are important elements of marine ecosystems, providing habitat and food for biota as well as playing a role in nutrient and gas cycling and coastal protection. Vegetation in marine systems takes various forms (e.g., size, shape) and may be relatively fixed or immobile (e.g., mangroves) or float along with ocean currents (e.g., Sargassum).

Annex 3.2: IUCN Global Ecosystem Typology

A3.29 Upper three levels of the IUCN GET (D. A. Keith et al., 2020). Realms listed are Terrestrial (T), Freshwater and saline wetlands (F), Marine (M), Subterranean (S), and transitions between these.

Realm	Biome	Ecosystem Functional Group
Terrestrial	T1 Tropical–subtropical forests	T1.1 Tropical-subtropical lowland rainforests
		T1.2 Tropical-subtropical dry forests and scrubs
		T1.3 Tropical-subtropical montane rainforests
		T1.4 Tropical heath forests
	T2 Temperate–boreal forests & woodlands	T2.1 Boreal and temperate montane forests and woodlands
		T2.2 Deciduous temperate forests
		T2.3 Oceanic cool temperate rainforests
		T2.4 Warm temperate laurophyll forests
		T2.5 Temperate pyric humid forests
		T2.6 Temperate pyric sclerophyll forests and woodlands
	T3 Shrublands & shrubby woodlands	T3.1 Seasonally dry tropical shrublands
		T3.2 Seasonally dry temperate heaths and shrublands
		T3.3 Cool temperate heathlands
		T3.4 Rocky pavements, lava flows and screes
	T4 Savannas and grasslands	T4.1 Trophic savannas
		T4.2 Pyric tussock savannas
		T4.3 Hummock savannas
		T4.4 Temperate woodlands
		T4.5 Temperate subhumid grasslands
	T5 Deserts and semi-deserts	T5.1 Semi-desert steppes
		T5.2 Thorny deserts and semi-deserts
		T5.3 Sclerophyll deserts and semi-deserts
		T5.4 Cool deserts and semi-deserts
		T5.5 Hyper-arid deserts
	T6 Polar-alpine (cryogenic)	T6.1 Ice sheets, glaciers and perennial snowfields
		T6.2 Polar-alpine rocky outcrops
		T6.3 Polar tundra and deserts
		T6.4 Temperate alpine grasslands and shrublands
		T6.5 Tropical alpine grasslands and shrublands
	T7 Intensive land-use	T7.1 Annual croplands
		T7.2 Sown pastures and fields
		T7.3 Plantations
		T7.4 Urban and industrial ecosystems
		T7.5 Derived semi-natural pastures and old fields
Freshwater	F1 Rivers and streams	F1.1 Permanent upland streams
		F1.2 Permanent lowland rivers
		F1.3 Freeze-thaw rivers and streams
		F1.4 Seasonal upland stream
		F1.5 Seasonal lowland rivers
		F1.6 Arid episodic arid rivers
		F1.7 Large lowland rivers
	F2 Lakes	F2.1 Large permanent freshwater lakes
		F2.2 Small permanent freshwater lakes
		F2.3 Seasonal freshwater lakes
		F2.4 Freeze-thaw freshwater lakes
		F2.5 Ephemeral freshwater lakes
		F2.6 Permanent salt and soda lakes
		F2.7 Ephemeral salt lakes

		F2.8 Artesian springs and oases
		F2.9 Geothermal pools and wetlands
		F2.10 Subglacial lakes
	F3 Artificial fresh waters	F3.1 Large reservoirs
		F3.2 Constructed lacustrine wetlands
		F3.3 Rice paddies
		F3.4 Freshwater aquafarms
		F3.5 Canals, ditches and drains
Freshwater-Terrestrial	TF1 Palustrine wetlands	TF1.1 Tropical flooded forests and peat forests
		TF1.2 Subtropical-temperate forested wetlands
		TF1.3 Permanent marshes
		TF1.4 Seasonal floodplain marshes
		TF1.5 Episodic arid floodplains
		TF1.6 Boreal, temperate and montane peat bogs
		TF1.7 Boreal and temperate fens
Freshwater-Marine	FM1 Semi-confined transitional waters	FM1.1 Deepwater coastal inlets
		FM1.2 Permanently open riverine estuaries and bays
		FM1.3 Intermittently closed and open lakes and lagoons
Marine	M1 Marine shelfs	M1.1 Seagrass meadows
		M1.2 Kelp forests
		M1.3 Photic coral reefs
		M1.4 Shellfish beds and reefs
		M1.5 Photo-limited marine animal forests
		M1.6 Subtidal rocky reefs
		M1.7 Subtidal sand beds
		M1.8 Subtidal mud plains
		M1.9 Upwelling zones
	M2 Pelagic ocean waters	M2.1 Epipelagic ocean waters
		M2.2 Mesopelagic ocean waters
		M2.3 Bathypelagic ocean waters
		M2.4 Abyssopelagic ocean waters
		M2.5 Sea ice
	M3 Deep sea floors	M3.1 Continental and island slopes
		M3.2 Submarine canyons
		M3.3 Abyssal plains
		M3.4 Seamounts, ridges and plateaus
		M3.5 Deepwater biogenic beds
		M3.6 Hadal trenches and troughs
		M3.7 Chemosynthetically-based ecosystems
	M4 Anthropogenic marine systems	M4.1 Submerged artificial structures
		M4.2 Marine aquafarms
Marine-Terrestrial	MT1 Shoreline systems	MT 1.1 Rocky shorelines
		MT 1.2 Muddy shorelines
		MT 1.3 Sandy shorelines
		MT 1.4 Boulder and cobble shorelines
	MT2 Supralittoral coastal systems	MT 2.1 Coastal shrublands and grasslands
	MT3 Anthropogenic shorelines	MT 3.1 Artificial shorelines
Marine-Freshwater-Terrestrial	MFT1 Brackish tidal	MFT1.1 Coastal river deltas
		MFT1.2 Intertidal forests and shrublands
		MFT1.3 Coastal saltmarshes and reedbeds
Subterranean	S1 Subterranean lithic	S1.1 Aerobic caves
		S1.2 Endolithic systems
	S2 Anthropogenic subterranean voids	S2.1 Anthropogenic subterranean voids

Subterranean-Freshwater	SF1 Subterranean freshwaters	SF1.1 Underground streams and pools SF1.2 Groundwater ecosystems
	SF2 Anthropogenic subterranean freshwaters	SF2.1 Water pipes and subterranean canals SF2.2 Flooded mines and other voids
Subterranean-Marine	SM1 Subterranean tidal	SM1.1 Anchialine caves SM1.2 Anchialine pools SM1.3 Sea caves

Source: D. A. Keith et al. (2020).

4 Accounting for ecosystem extent

4.1 Purpose in accounting for ecosystem extent

4.1 A common starting point for ecosystem accounting is the organization of information on the extent of different ecosystem types within a country or other EAA, and how that extent is changing over time. ***Ecosystem extent is the size of an ecosystem asset***. It is usually measured in terms of spatial area but may also be measured in terms of length or volume. Extent data are summarised in an ecosystem extent account.

4.2 Accounting for ecosystem extent is relevant for four reasons. First, an ecosystem extent account provides a common basis for discussion of the composition (mix/combination) of, and changes in, ecosystem types within a country. This information supports the derivation of coherent indicators of deforestation, desertification, agricultural conversion, urban expansion and other forms of ecosystem change; supports the measurement of ecosystem diversity and the derivation of indicators of changes in biodiversity; and when information underpinning an extent account is mapped, supports an understanding of the locations and configuration of ecosystem types within an EAA and how this is changing over time (e.g., with respect to fragmentation of the landscape, or the proximity of cultivated areas to natural ecosystems).

4.3 Second, given a core intent of ecosystem accounting is to mainstream ecological data in economic planning and decision making, the organisation of data on ecosystem extent provides a straightforward but meaningful entry point to the discussion of ecosystems for those less familiar with ecological concepts and data. In particular, extent accounts provide a common framing through which other data about ecosystems can be presented. For example, where relevant data are available, mapped data about ecosystem condition and ecosystem service flows can be tabulated using a common classification of ecosystem types.

4.4 Third, the structure of the ecosystem extent account, as set out below, demonstrates in an accessible and readily interpreted way, the capability of accounting to provide a time series narrative, in this case through the estimation of opening and closing balances over an accounting period. Recording a time series is particularly important to reveal the degree to which the extent and composition of ecosystem types has changed, and the nature of conversions between ecosystem types.

4.5 Fourth, the spatial data most commonly used to compile an ecosystem extent account provides an underlying infrastructure for the measurement of ecosystem condition and for the measurement and modelling of many ecosystem services. In both cases, the relevant indicators of condition and services will commonly vary by ecosystem type and will depend on the location and configuration (spatial arrangement) of ecosystem types within an EAA. Further, the ecosystem extent account and ecosystem condition account will provide most information when viewed and interpreted jointly.

4.2 Ecosystem extent accounts

4.2.1 Scope of extent accounts

4.6 Following the principles described in Chapter 3, an ecosystem extent account is compiled for the total area of an EAA. Thus, an ecosystem extent account records the areas and changes in areas, of all of the ecosystem assets within an EAA, classified by ecosystem type, i.e., the areas of all ecosystem assets of the same ecosystem type are aggregated. Since input data are commonly spatial data available in the form of maps, mapped outputs can also be produced where all of the ecosystem assets of the same ecosystem type are coded equivalently. Further, in this case, extent accounts reflect tabulated outputs of the mapped input data.

4.7 In concept, at the national level, the EAA extends to cover all terrestrial, freshwater and marine ecosystems with a boundary set by the country's border with other countries and its EEZ.[42]

4.8 Compilers may choose to use an EAA of smaller geographical scope – for example using a focus on the terrestrial or marine realm, or a focus on a sub-national region. Also, it is possible to compile accounts covering areas outside national jurisdiction, for example for oceans areas including the high seas. These may be compiled as part of regional or international accounting efforts.

4.9 Complementary extent accounts can be compiled for ecosystem types that are outside the scope of the standard two dimensional extent account, such as for subterranean ecosystems and aquifers. Complementary accounts can also be compiled for linear features reflecting a one dimensional perspective noting that the area associated with linear features will be included in scope of the standard two dimensional extent accounts following the treatments outlined in section 3.3. Potential structures for complementary extent accounts are described in section 4.2.4.

4.2.2 Structure of extent accounts and accounting entries

4.10 The structure of an ecosystem extent account is shown in Table 4.1. The structure of the rows reflects the general logic of asset accounts as described in the SEEA Central Framework, with an opening extent, closing extent, and additions and reductions in extent. Entries are in terms of area using measurement units appropriate for the scale of analysis, e.g., hectares, square kilometres.

4.11 The column headings correspond to the classes of the selected ecosystem type classification. In Table 4.1, these classes are examples of ecosystem types at the ecosystem functional group (level 3) of the SEEA ET reference classification based on the IUCN GET, as described in Chapter 3 and presented in Annex 3.2. Table 4.1 includes ecosystem types from terrestrial, freshwater and marine realms. It may be appropriate to compile accounts separately for each of these realms, particularly if the available units of measurement are different.

4.12 At national or sub-national level, it will be most appropriate to compile accounts using an existing ecosystem type classification and to make a correspondence to the SEEA Ecosystem Type reference classification for the purpose of international comparison.

4.13 From an accounting perspective, there is no specific limit on the number of ecosystem types or the level of detail that is included. The choice will depend on the relevance of different ecosystem types and data availability. The overall constraint is that the sum of the areas of all ecosystem types must be equal to the total area of the EAA.

[42] Sub-surface ecosystems, such as subterranean ecosystems and aquifers are excluded from the primary extent account as their area cannot be added with the area of other realms without double counting

Table 4.1: Ecosystem extent account (units of area)*

	Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																		
Realm	Terrestrial												Freshwater			Marine			
Biome	T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				…		T7		F1	…	FM1	M1	…	MFT1	
Selected Ecosystem Functional Group (EFG)	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	…	Temperate pyric sclerophyll forests and woodlands	…	…	…	Derivied semi-natural pastures and old fields	Permanent upland streams	…	Intermittently closed and open lakes and lagoons	Seagrass meadows	…	Coastal saltmarshes and reedbeds	
	T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	…	T2.6	…	…	…	T7.5	F1.1	…	FM1.3	M1.1	…	MFT1.3	**TOTAL**
Opening extent																			
Additions to extent																			
Managed expansion																			
Unmanaged expansion																			
Reductions in extent																			
Managed reductions																			
Unmanaged reductions																			
Net change in extent																			
Closing extent																			

* This table provides an indicative structure with respect to the set of ecosystem types. Compilation will require the use of nationally selected ecosystem types.

4.14 The accounting entries encompass opening and closing extent, additions to extent and reductions in extent. The following treatments should be applied noting that, depending on data availability, it may not be possible to record all accounting entries that distinguish the different types of additions and reductions. In this case, it is sufficient to record the opening and closing extents and the net change in different ecosystem types. This level of detail can still provide important information on trends in ecosystem extent.

4.15 Relevant accounting entries are:

- Opening and closing extent represent the total area of ecosystem assets for a given ecosystem type at the beginning and end of an accounting period, generally one year.
- Additions to extent represent increases in the area of an ecosystem type. Where possible, to support understanding the nature of the additions and possible policy responses, additions to extent should be separated into managed expansions and unmanaged expansions.
    - Managed expansion represents an increase in the area of an ecosystem type due to direct human activity in the ecosystem, including the unplanned effects of such activity. Examples include the conversion of forests into cultivated land or land reclamation work in coastal areas. Human activity may also create new areas of more natural ecosystem types, for example by the reforestation of cultivated areas.
    - Unmanaged expansion represents an increase in area of an ecosystem type resulting from natural processes, including seeding, sprouting, suckering or layering. Unmanaged expansion can be influenced by human activity, for example, the expansion of deserts due to the effects of climate change, or result from abandonment of land by people.
- Reductions in extent represent decreases in the area of an ecosystem type. Where possible, to support understanding the nature of the reductions and possible policy responses, reductions in extent should be separated into managed reductions and unmanaged reductions.
    - Managed reduction represents a decrease in the area of an ecosystem type due to direct human activity in the ecosystem, including the unplanned effects of such activity, or cases where the activity may be illegal. Examples include deforestation and increases in urban areas.
    - Unmanaged reduction represents a decrease in area of an ecosystem type associated with natural processes. Unmanaged regression can be influenced by human activity for example the loss of coral reefs due to the effects of climate change, or result from abandonment of land by people.

4.16 All additions and reductions in extent are considered ecosystem conversions and imply a change in the ecosystem type. In defining an ecosystem conversion, it is not sufficient that there is a change in the condition of an ecosystem since this does not necessarily involve a change in ecosystem type. In particular, it is noted that the effects of extreme events, for example, bushfires or hurricanes, where there may be considerable loss of vegetation, soil or other ecosystem components, need not imply a change of ecosystem type. Indeed, most commonly these events will be followed by a period of regeneration and, generally speaking, patterns of disturbance should be expected. Section 4.2.3 provides further discussion of ecosystem conversions. In practice, it may be useful to compile ecosystem type change matrices (see section 4.3.2) to support compilation of measures of managed and unmanaged changes.

4.17 The availability of updated input data or changed methods, for example, from new or re-interpreted satellite imagery, may permit a reassessment of the size of the area of different ecosystem types. Where such changed data and methods are used, it will likely require the revision of previous estimates to ensure a continuity of time series. Time series may also be revised when updated classifications are applied. No distinct entry for revisions is recorded in the accounts. Rather the individual entries for opening and closing extent and additions and reductions are altered. For analytical and dissemination purposes, it may be appropriate to show the size of the revisions by calculating the difference between estimates from historical and revised accounts for the same accounting period.

4.18 Generally, additions to one ecosystem type will be matched by an entry for reductions in another ecosystem type, for example an increase in cultivated land may be matched by a reduction in woodlands. If there is a change in the total area of the EAA, a matching entry is not recorded.

4.19 Changes in the total area of an EAA due to political factors (e.g., changes following a realignment of borders) should be recorded as managed expansions or reductions for the relevant ecosystem types. These changes do not require revisions to past accounts although it may be of analytical interest to compile historical information pertaining to ecosystem assets within the changed boundaries.

4.20 The area of an EAA for a national jurisdiction including marine, terrestrial and freshwater realms is unlikely to change significantly from the opening to the closing stock. Hence, the total area recorded in the right-hand column of Table 4.1 will generally be the same for the opening and closing extent and hence the total additions will equal the total reductions.

4.21 However, changes at the edges of the realms and associated transition areas, particularly between the marine and terrestrial realms are likely to occur, for example through coastal erosion, sediment deposition and aggradation and sea level rise, or due to land reclamation work. The associated changes in ecosystem type will need to be accounted for.

4.22 For the ecosystem extent account presented in Table 4.1, there is no requirement that the areas recorded for each ecosystem type are contiguous. That is, the total area of, for example, Trophic savannas (T4.1), is likely to be spread out across an EAA in distinct ecosystem assets. The locations of the ecosystem types will be apparent when extent data are presented in maps.

4.2.3 Recording ecosystem conversions

4.23 The ecosystem extent account records changes in ecosystem type. These changes are collectively referred to as ecosystem conversions. ***Ecosystem conversions refer to situations in which, for a given location, there is a change in ecosystem type involving a distinct and persistent change in the ecological structure, composition and function which, in turn, is reflected in the supply of a different set of ecosystem services.***

4.24 Ecosystem conversions are of particular interest in understanding trends in and impacts on biodiversity and flows of ecosystem services. Identification of ecosystem conversions relies on determining the time at which the opening extent is recorded, the length of the accounting period and identification of the differences between ecosystem types. These issues are discussed in this section.

4.25 Generally, the length of the accounting period is one year and this will be an appropriate reporting period to record managed expansions and reductions since the change from one ecosystem type to another can be readily determined as having occurred during the accounting period. Time frames for unmanaged expansions and reductions may, however, vary considerably and hence determining the appropriate accounting period in which the conversion should be recorded may be more difficult.

4.26 When there are extreme events and it is expected that the ecosystem will recover from the effects, it is appropriate to record no change in ecosystem type, i.e., the change may be considered to be part of normal patterns of disturbance. In this case, changes in patterns of disturbance (e.g., more frequent fires) are likely to be better represented as changes in condition. A similar treatment should apply in the case of seasonal changes in extent, for example, sea ice, since these changes may be considered part of normal ecosystem dynamics. Where appropriate, seasonal changes may be recorded in sub-annual extent accounts.

4.27 Where changes are gradual and longer term, for example changes in coral reefs due to ocean acidification, initial changes may be most appropriately recorded as changes in the condition of the ecosystem asset. However, at some point in time, the ecosystem may be considered to have changed sufficiently in terms of its ecological structure, composition and function to be considered a different ecosystem type. This assessment may consider information collected in the measurement of ecosystem condition and relevant limits and thresholds. Such changes in ecosystem type for a given location should be recorded as an expansion or reduction in the extent account in the accounting period in which it is determined that the change took place.

4.28 Even though determining the precise time at which an ecosystem conversion takes place may be a matter of ecological uncertainty, by adopting an annual reporting approach, there will be a clear recording structure in place that ensures consideration of changes on a regular basis and allows changes to be recorded at appropriate points in time.

4.29 Due to data and resource limitations, it may not be possible to compile annual extent accounts. This outcome should not be interpreted as meaning that changes in ecosystem extent over time are necessarily slow or are insignificant on an annual basis. While this may be the case in some instances, the significance of recording changes in the composition and configuration of ecosystem types in a timely fashion cannot be underestimated. It is noted as well that the increasing availability of remote sensing and similar data sets is reducing the barriers to regular compilation. These data may also support the use of benchmarking and interpolation techniques to provide up-to-date information on ecosystem extent to support policy and analysis.

4.30 A common intent in ecosystem extent accounting is to record differences between the current composition of ecosystem types and a reference or baseline composition. Depending on the purpose of analysis, this may involve estimation over long periods of time, for example comparing current measures of extent to a pre-industrial revolution composition. Conceptually, it is straightforward to compile extent accounts to compare two, or more, points in time that are considerably separated in time. For instance, using the same structure as shown in Table 4.1, the opening extent could be estimated for 1970 and the closing extent estimated for 2015.

4.31 The structure of Table 4.1 allows for recording changes that are managed and unmanaged. Depending on the availability of data and policy interest, an extension to the ecosystem extent account may be developed to classify ecosystem conversions by the reasons for change. Examples of reasons include urban expansion, salinization, and afforestation.[43]

[43] Proposals for classifying conversions are described in UNCCD (2017) in relation to the measurement of SDG indicator 15.3.1 concerning land degradation.

4.3 Complementary presentations of ecosystem extent data

4.3.1 Mapping ecosystem extent

4.32 Significant analytical benefits are likely to arise from presenting maps of ecosystem extent which show the configuration of ecosystem assets by different ecosystem types across an EAA. Analysis of a time series of extent maps will also enable analysis of the location of changes in ecosystem types. In particular, mapping ecosystem extent can reveal patterns of changing fragmentation of ecosystem assets. These types of changes will not be evident when data are presented in tabular form.

4.33 Spatially detailed data on the area of ecosystem assets can also be used to derive a range of supporting indicators, some of which may be relevant in assessing the condition of ecosystems, in particular concerning characteristics related to fragmentation and connectivity of ecosystems. Example of such indicators include measures of the number occurrences of an ecosystem type (number of patches); average patch size; and edge length.

4.3.2 Ecosystem type change matrix

4.34 Using spatially detailed data, additional detail on the nature of ecosystem conversions may be obtained by comparing maps from two periods to compile an ecosystem type change matrix. The ecosystem type change matrix set out in Table 4.2 shows the area of different ecosystem types at the beginning of the accounting period (opening extent); the increases and decreases in this area according to the ecosystem type it was converted from (in the case of increases) or the ecosystem type it was converted to (in the case of decreases) and, finally, the area covered by different ecosystem types at the end of the accounting period (closing extent). It is assumed here that the total area of the EAA is unchanged between the two points in time. Where the EAA has changed in size, a choice will be needed on which point in time should be used to define the total area for comparison. The default option is the EAA with the smaller area since this will provide complete data coverage for two points in time.

4.35 By way of example, for the ecosystem type Tropical-subtropical lowland rainforests (T1.1), the opening extent is recorded in the right-hand column of the first row and the closing extent is recorded in the bottom row of the left-hand column. Where the ecosystem type in a particular location does not change, i.e., there is no ecosystem conversion, then the total unchanged area is recorded along the diagonal from top left to bottom right. Where there is a change in an ecosystem type (i.e., an ecosystem conversion), an entry is made at the intersection of the row related to the original ecosystem type (i.e., the ecosystem type that is reducing in area) and the column relating to the new ecosystem type (i.e., the ecosystem type that is increasing in area). For example, a conversion from ecosystem type T1.1 to Derived semi-natural pastures (T7.5) would be recorded in the cell corresponding to the row for T1.1 and the column for T7.5. Recording in this way for each ecosystem type ensures that (a) the sum of all cells across a row will equal the opening extent (i.e., unchanged areas plus the reduction in area); and (b) the sum of all cells in a column will equal the closing extent (i.e., unchanged areas plus the additions to area).[44]

[44] An alternative presentation of a change matrix is included in the SEEA Central Framework, Figure 5.14 for land cover.

Table 4.2: ET change matrix (units of area)

	Realm	Biome			Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology) Closing Extent																		
					Terrestrial												Freshwater			Marine			
					T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1	
			Selected Ecosystem Functional Group (EFG)		Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	...	Temperate pyric sclerophyll forests and woodlands	...	...	...	Derivied semi-natural pastures and old fields	Permanent upland streams	...	Intermittently closed and open lakes and lagoons	Seagrass meadows	...	Coastal saltmarshes and reedbeds	Opening
					T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3	
Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology) Opening Extent	Terrestrial	T1 Tropical-subtropical forests	Tropical-subtropical lowland rainforests	T1.1																			
			Tropical-subtropical dry forests and scrubs	T1.2																			
			Tropical-subtropical montane rainforests	T1.3																			
			Tropical heath forests	T1.4																			
		T2 Temperate-boreal forests and woodlands	Boreal and temperate high montane forests and woodlands	T2.1																			
			Deciduous temperate forests	T2.2																			
			...	...																			
			Temperate pyric sclerophyll forests and woodlands	T2.6																			
		...	...	...																			
			...	...																			
		T7	...	...																			
			Derivied semi-natural pastures and old fields	T7.5																			
	Freshwater	F1	Permanent upland streams	F1.1																			
		...	...	...																			
		FM1	Intermittently closed and open lakes and lagoons	FM1.3																			
	Marine	M1	Seagrass meadows	M1.1																			
		...	...	...																			
		MFT1	Coastal saltmarshes and reedbeds	MFT1.3																			
				Closing																			

4.3.3 *Extent accounts for linear features and sub-surface ecosystems*

4.36 Conceptually, most ecosystem assets have a two-dimensional footprint geometry, allowing their extent to be measured by their area. However, for some ecosystem assets this approach is not appropriate because their length far exceeds their width, such that their footprint geometry is effectively one-dimensional. Typical examples are streams, smaller rivers and road verges. These are collectively referred to as linear features.

4.37 A complementary extent account for linear features can be compiled by recording the length of each individual linear feature (each being treated as an ecosystem asset). Each linear feature can also be assigned to an ecosystem type allowing aggregation by type of linear feature. It will be relevant to distinguish clearly between linear features dominated by produced assets (e.g., roads) and those that are more natural (e.g., streams). Classification following the IUCN GET classes would be appropriate. This accounting follows the same logic as for a two-dimensional extent account (as described above) but uses length units instead of area units. The resulting one-dimensional extent account can complement a two-dimensional extent account, noting that the total one-dimensional length cannot be aggregated with total two-dimensional area due to the different dimensionality.

4.38 An example of a presentation showing this distinction is presented in Table 4.3 where (larger) rivers are shown having both area and length while smaller rivers and streams are recorded as having only length. The fact that narrow linear features have an assumed area of zero, does not disqualify them from being ecosystem assets with an associated condition or the potential to supply ecosystem services.

Table 4.3: Presentation of closing balances including both one and two dimensional ecosystem types

Ecosystem type		Extent: Area (km^2)	Extent: Length (km)
2D	Forest	345	
	Lakes	50	
1D	Rivers	5	50
	Streams		200
Total		**400**	**250**

4.39 Complementary extent accounts can also be compiled for sub-surface ecosystem assets including subterranean ecosystem and aquifers. Following the classification of ecosystem types, accounts could be compiled showing the number of occurrences, the area or footprint of these ecosystems and, potentially, the volume of the ecosystems. As appropriate, these indicators of ecosystem extent may be complemented by data on ecosystem condition and ecosystem services.

4.3.4 *Linking extent accounts and economic data*

4.40 Across all SEEA accounts there is a general ambition to link environmental data to measures of economic activity. In the context of the ecosystem extent accounts, a primary means by which this can be undertaken is by linking data on ecosystem extent by ecosystem type with data on the economic owners or managers of the ecosystem assets. Data on economic owners may be classified by institutional sector following the classes in the 2008 SNA such as non-financial corporations, general government and households. This classification is most relevant in understanding the ownership and financing context. In some cases, there may be particular interest in identifying the area of ecosystems (and the different ecosystem types) that are under common ownership or under the control of indigenous people.

4.41 Data on economic managers or by type of economic activity may be classified by ISIC class, such as agriculture, forestry, water supply, and then aligned to the structure of supply and use tables. This classification of data is most relevant in understanding the links between ecosystems and economic activity and understanding those industries with the rights to access and use ecosystems. The distinction between ownership and type of activity is important since the same ecosystem type may be linked to a range of different ownership contexts and uses.

4.42 The set of ownership and type of activity classes that are developed will depend on the data available and the purpose of analysis. Tables that to show the connection between ecosystem types and economic ownership and management can provide a range of information. For example, they may describe the mix of ecosystem types that are managed by government as distinct from the household sector, or the various ecosystem types managed by the agricultural industry.

4.43 An example of a table showing a cross-classification of ecosystem assets is provided in Table 4.4. It shows ecosystem types (in this case EFG classes) in the columns and types of economic units in rows for a single point in time, for example the closing of the accounting period. The classes of economic units shown here reflects a production or management perspective and thus industrial classes are prominent. An alternative set of classes reflecting economic ownership by institutional sector (e.g., non-financial corporations, financial corporations, general government, households) may also be developed. Extent data classified by economic use and ownership should be maintained as distinct data layers and cross-tabulated or mapped when required.

Table 4.4: Ecosystem extent by type of economic unit (units of area)

		Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																		
	Realm	Terrestrial												Freshwater			Marine			
	Biome	T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1	
	Selected Ecosystem Functional Group (EFG)	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	...	Temperate pyric sclerophyll forests and woodlands	...	...	...	Derivied semi-natural pastures and old fields	Permanent upland streams	...	Intermittently closed and open lakes and lagoons	Seagrass meadows	...	Coastal saltmarshes and reedbeds	TOTAL
		T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3	
Closing extent by economic unit																				
Agriculture, forestry and fishin	ISIC A																			
Agriculture																				
Forestry																				
Fishing																				
Mining and quarrying	ISIC B																			
Manufacturing	ISIC C																			
Electricity, gas, steam and air conditioning supply	ISIC D																			
waste management and remediation activities	ISIC E																			
Services																				
Other industries																				
Government																				
Households																				
TOTAL																				

4.44 Information linking ecosystem extent to economic units is of particular importance in the design and implementation of policy since the outcomes with respect to specific ecosystem types are likely to be highly influenced by the characteristics of the owning or managing economic units. It is likely that this type of analysis is of most relevance for terrestrial ecosystems but in certain contexts, for example in relation to marine spatial planning, the types of ownership and access rights will also be of relevance.

4.45 The structural information on the links between ecosystem assets and economic units such as presented in Table 4.4 also provides the basis for creating links between economic units and data from other ecosystem accounts, in particular ecosystem services flow accounts.

5 Accounting for ecosystem condition

5.1 Introduction

5.1.1 The measurement focus in accounting for ecosystem condition

5.1 A central feature of ecosystem accounting is its organization of biophysical information on the condition of different ecosystem assets and ecosystem types within an EAA. Ecosystem condition accounts provide a structured approach to recording and aggregating data describing the characteristics of ecosystem assets and how they have changed.

5.2 ***Ecosystem condition is the quality of an ecosystem measured in terms of its abiotic and biotic characteristics***. Condition is assessed with respect to an ecosystem's composition, structure and function which, in turn, underpin the ecosystem integrity of the ecosystem, and support its capacity to supply ecosystem services on an ongoing basis. Measures of ecosystem condition may reflect multiple values and may be undertaken across a range of temporal and spatial scales.

5.3 Measurement of ecosystem condition is of significant interest in supporting environmental policy and decision making, which is often focused on identifying ecosystems of particular concern and then protecting, maintaining and restoring their condition. Comprehensive and comparable measures of ecosystem condition that are compiled regularly are therefore of direct relevance.

5.4 Ecosystem condition accounts complement environmental monitoring systems by using data from different monitoring systems, for example concerning biodiversity, water quality and soil properties. The intention of the ecosystem condition account is therefore to build upon and synthesise, rather than replace, existing monitoring systems. Further, as described in more detail in section 5.6, ecosystem condition accounts provide a means to mainstream a wide range of ecological concepts and data into economic and development planning processes, and the regular production of ecosystem condition accounts may in turn help systematise and strengthen existing monitoring systems.

5.5 Ecosystem condition accounts are not intended to directly assess climate patterns although climate is a determining factor in the types of ecosystems that are observed. However, in some cases climate related variables such as temperature and precipitation will be relevant in the assessment of the condition of local ecosystems; and other variables, such as species richness, may be affected by broader patterns of climate change. Consequently, analysis of climate patterns can support measurement of ecosystem condition.

5.6 Although the recording of the condition of assets is not a standard output within economic accounts, measurement of, and assumptions regarding, asset condition are inherent in accounting for assets. For example, in estimating rates of deterioration in the measurement of depreciation of produced assets, generally, it is assumed that the condition of an asset is embodied in its current market price. Since ecosystem assets do not usually have a market price, explicit recording of ecosystem condition in physical terms is an important aspect of completing the accounting picture.

5.7 A primary benefit of compiling ecosystem condition accounts stems from using an approach to compiling data on different aspects of ecosystem condition that supports alignment with other data on ecosystems, for example concerning ecosystem extent and ecosystem services. This structured approach – based on a common understanding of the size, composition, function, location and types of ecosystem assets – offers insight into changes that is more comprehensive than provided by individual data sets.

5.1.2 Ecological concepts underpinning the measurement of ecosystem condition

5.8 The concept of ecosystem condition used in the SEEA EA is based on long-standing ecological knowledge and is related to several other terms that are used in the scientific literature or in legislation that aims to assess and protect ecosystems (D. A. Keith et al., 2020). Although these terms may look different, the underlying concepts are overlapping, with differences reflecting the fact that they have been developed and used by different research communities for different ecosystem types.

5.9 Ecosystem condition is often defined by measuring the similarity (or the distance) of a current ecosystem to a reference state, such as minimally impacted by people or a historical state (Costanza, 1992; Palmer & Febria, 2012). Ecosystem condition can be described by assessing combinations of physical, chemical and biological indicators and their changes over time, an approach commonly used by water managers to assess the state of wetlands, rivers and lakes, and subsequently adapted to marine and terrestrial ecosystems. Naturalness and intactness or the opposite term hemeroby are sometimes also used to describe the distance of an ecosystem from an (undisturbed) reference. It must be recognised that humans have modified or replaced natural ecosystems over large parts of the globe and hence the measurement of ecosystem condition also needs to be suitable for semi-natural and anthropogenic ecosystems.

5.10 In ecology, the description of ecosystem condition is strongly rooted in the concept of ecosystem integrity, which implies an unimpaired condition of being complete or undivided (Karr, 1993). ***Ecosystem integrity is defined as the ecosystem's capacity to maintain its characteristic composition, structure, functioning and self-organisation over time within a natural range of variability*** (Pimentel & Edwards, 2000). Ecosystems with high integrity or condition are typically more resilient, i.e., more able to recover from disturbances or to adapt to environmental changes (Holling, 1973).

5.11 Not all ecosystems, regardless of their condition, are equally resilient. Shoreline systems or estuaries for instance are often exposed to a highly dynamic environment and they have evolved to be able to absorb or recover from disturbances. In contrast, fragile ecosystems that often exist under extreme resource limitations in terms of water, nutrients or temperature, for example sphagnum bogs or alpine herb fields can be in a good condition but have a low level of resilience as they may quickly collapse into a degraded state even under light pressure.

5.12 Biodiversity (the diversity within and between species and of ecosystems) is integral in measuring ecosystem condition, contributing to the composition, structure and function of ecosystems. For example, commonly used biodiversity metrics such as species abundance, species richness or species-based indices are often used to measure aspects of ecosystem condition, in particular composition (Rendon et al., 2019). The functional diversity of species gives support to ecosystem function (Cadotte et al., 2011), while fine scale diversity of ecological communities contributes to biodiversity within an ecosystem.

5.13 Ecosystem condition and ecosystem services are linked, but the relationship varies between different services, and often is not linear. For many services, ecosystems in better condition can support a greater quantity and quality of the relevant ecosystem services (see Smith et al. (2017) for a meta-analysis), providing an argument for sustainable ecosystem management. The relationship between ecosystem condition and service provision is central to the concept of ecosystem capacity (see Chapter 6).

5.14 Measures of ecosystem condition will be more comprehensive and integrative than measures of the capacity to supply specific ecosystem services. That is, characteristics of ecosystem condition, and their associated measured variables and indicators, should include more than those relevant to providing final ecosystem services used by humans.

5.15 These related concepts provide a strong scientific and statistical foundation for the SEEA EA to define ecosystem condition and to propose practical methods for implementation of ecosystem condition accounts using commonly applied variables and indicators. A key aspect of the accounting approach described here is that it encompasses consideration of both ecosystem conservation and the sustainable use of ecosystem services by humans.

5.1.3 General approach to compiling ecosystem condition accounts

5.16 The SEEA EA uses a three-stage approach to account for ecosystem condition. The move from one stage to the next requires a progressive building of data and the use of additional assumptions.[45] Outputs at each stage are relevant for policy and decision making.

5.17 Outputs from stages one and two comprise the ecosystem condition accounts, and correspond to the presentation of data on condition variables and condition indicators. Overall measures of ecosystem condition for multiple ecosystem types and multiple indicators can be undertaken in the optional third stage through the derivation of composite indices and applying appropriate aggregation approaches.

5.18 In ecosystem accounting, the condition of an ecosystem asset is interpreted as the ensemble of multiple relevant ecosystem characteristics, which are measured by sets of variables and indicators that in turn are used to compile the accounts. Variables and indicators are selected in relation to the context and purpose of assessment, and different considerations will be relevant across natural and anthropogenic ecosystems. Individual indicators can be aggregated to composite indices that provide a synthesis of the integrity, health or naturalness of an ecosystem asset.

5.19 Ecosystem condition accounts record data on the state and functioning of ecosystem assets within an EAA using a combination of relevant variables and indicators. The selected variables and indicators reflect changes over time in the key characteristics of each ecosystem asset. Ecosystem condition accounts are compiled in biophysical terms and the accounting structure provides the basis for organizing the data, aggregating across ecosystem assets of the same ecosystem type, and measuring change over time between the opening and closing points of accounting periods. The accounting approach described here builds from the level of ecosystem assets and, as described, may imply the need for direct field measurements for every ecosystem asset. In practice, this will not be possible and hence condition accounts will most commonly be compiled using remote sensing, modelling and other techniques in combination with available direct field measures.

5.20 The precise structure of ecosystem condition accounts will depend on the selected characteristics, data availability, uses of the accounts and policy applications. Ecosystem condition accounts are commonly compiled by ecosystem type because each type has distinct characteristics. For example, the characteristics of forests may include tree density and age, while for rivers, characteristics concerning water flow and quality will be relevant. However, some characteristics may be common across a number of ecosystem types, for example species richness or functional diversity will be relevant across all ecosystems, and other

[45] The approach described to accounting for ecosystem condition reflects the body of research summarised in H. Keith et al. (2020).

characteristics will be relevant to a combination of ecosystem types within a landscape or seascape,[46] for example the diversity among different ecosystem types.

5.21 The approach to accounting for ecosystem condition is spatially explicit. Aggregate measures, for example for an ecosystem type within an EAA, will therefore reflect a measure of the average condition of the constituent ecosystem assets. This will be appropriate for a range of policy and analytical contexts. However, particularly with respect to aggregate measures of biodiversity, it will be necessary to incorporate data about characteristics that are not attributable to individual ecosystem assets. For example, information on the total number of species across an EAA (a measure of gamma diversity), should be incorporated in an aggregate measure of biodiversity for an EAA. These issues are described further later in this chapter and also in Chapter 13 in the context of accounting for biodiversity.

5.22 A difference between scientific and policy aims in the development and use of condition indicators is that scientists aim to understand the complexity of ecosystems and encapsulate this reality, whereas policy-makers often need headline indicators of the ecosystem that can be evaluated readily together with indicators representing economic, social, political and other realities. Accounting aims to provide a connection between these perspectives and hence, individual variables, indicators and ecosystem condition indices all have a role in applying ecosystem condition accounts in decision making.

5.2 Defining and selecting characteristics and variables of ecosystem condition

5.2.1 Introduction

5.23 The first stage in measuring ecosystem condition involves setting the measurement focus and defining and selecting ecosystem characteristics and associated variables. This stage is important in underpinning the compilation of the second stage involving ecosystem condition indicators and the optional third stage of deriving aggregate measures of condition across multiple ecosystem types.

5.24 The primary spatial units are ecosystem assets and these are expected to be delineated such that they are reasonably homogeneous in terms of their main characteristics (see Chapter 3), a feature that will flow on to their condition too. Ideally, and subject to data availability, it is recommended that the condition variables are recorded for each ecosystem asset to ensure full reliability and transparency of the ecosystem condition accounts. Where data are available, measures of ecosystem condition may be mapped to highlight variations in condition across ecosystem assets.

5.25 Conceptually, it is possible to compile accounting tables for an individual ecosystem asset, such as a single wetland or cultivated area. Nevertheless, the measurement objective of the SEEA EA is to provide information about the changes in ecosystem-related stocks and flows in relatively large and diverse areas, so there is no expectation that all individual assets should be represented in a tabular form in the accounts.

5.26 The accounts shown here include entries for opening and closing condition, i.e., pertaining to observations on the state of the ecosystems at the beginning and end of an accounting period. If required, accounts can incorporate entries to show a more complete time series although in this case alternative configurations for the account tables will likely be required. Ecosystem condition accounts should also present important pieces of additional information (e.g.,

[46] A landscape or seascape (including those involving freshwater) is defined for accounting purposes as a group of contiguous, interconnected ecosystem assets representing a range of different ecosystem types.

concerning measurement units and reference levels) that clearly document the flow of information from raw data to high level indices.

5.27 Further, for clarity of presentation, the accounts shown here include entries only for a single ecosystem type. Extensions of the accounting structure to include additional ecosystem types (or the compilation of separate accounts for each ecosystem type) should follow the same broad structure for each ecosystem type, accepting the need to record different variables and indicators.

5.2.2 Ecosystem condition characteristics

5.28 ***Ecosystem characteristics are the system properties of the ecosystem and its major abiotic and biotic components (water, soil, topography, vegetation, biomass, habitat and species).*** Examples of characteristics include vegetation, water quality and soil type. The term ecosystem characteristics is intended to encompass all of the perspectives required to describe the long term, 'typical behaviour' of an ecosystem. Characteristics include the attributes of an ecosystem asset including components, structure, processes, and functionality. Ecosystem characteristics may be stable in nature, such as soil type or topography, or dynamic and changing as a result of both natural processes and human activity, such as precipitation and temperature, water quality and species abundance.

5.29 Ecosystems have many characteristics, and there is no requirement to integrate all of them into condition accounts. Appropriate selection of the relevant characteristics is discussed in section 5.2.4, together with the selection of ecosystem variables. Generally, the focus in assessing condition will be on characteristics that can show a directional change over consecutive accounting periods in a scientifically sound way. However, data on stable characteristics should also be collected. These data are often of direct relevance in the delineation of ecosystem assets and the modelling of flows of ecosystem services. Generically, these types of data are referred to as ancillary data and encompass data that are used in the compilation of accounts but may not be directly reported in ecosystem accounts. Beyond stable ecosystem characteristics, ancillary data includes data on demographics, emissions of pollutants, agricultural management practices such as fertilizer application and irrigation, types of natural resource management and expenditure on ecosystem restoration (Czúcz et al., 2021a).

5.2.3 Ecosystem condition typology

5.30 ***The SEEA ecosystem condition typology (ECT) is a hierarchical typology for organizing data on ecosystem condition characteristics.*** By describing a meaningful ordering and coverage of characteristics, it can be used as a template for variable and indicator selection and provide a structure for aggregation. The ECT also establishes a common language to support increased comparability among different ecosystem condition studies.

5.31 Ecosystems and their characteristics are highly complex, and hence the ECT provides a balance that meets the requirements for statistical purposes and is also ecologically meaningful in terms of ecosystem structure, function and composition. Since different ecosystem types have different characteristics, which in turn should be described by different variables and indicators, the ECT is designed to be universal. Thus, it is expected to be relevant for all realms and biomes, while also supporting direct reference to ecosystem-specific metrics at lower levels. Section 5.5.2 provides an indicative set of ecosystem condition variables for biomes structured according to the ECT. More detail about each ECT class, and their relationships to other relevant classification systems is given by Czúcz et al. (2021a).

5.32 The ECT has six classes as listed in Table 5.1. This typology can be applied for ecosystem characteristics, as well as for ecosystem condition variables and indicators, for which it is used to create a reporting and aggregation structure. The classification derives a set of ecosystem condition groups and classes with the common aim of being exhaustive and mutually exclusive (each metric can only be assigned to one class). It must be recognized that composition, structure, and particularly function are extremely broad concepts, that may be interpreted in different ways. To avoid ambiguities, and to ensure the *mutual exclusivity* of the classes, the following interpretations for each class should be applied.

Table 5.1: The SEEA Ecosystem Condition Typology (ECT)

ECT groups and classes
Group A: Abiotic ecosystem characteristics
Class A1. Physical state characteristics: physical descriptors of the abiotic components of the ecosystem (e.g., soil structure, water availability)
Class A2. Chemical state characteristics: chemical composition of abiotic ecosystem compartments (e.g., soil nutrient levels, water quality, air pollutant concentrations)
Group B: Biotic ecosystem characteristics
Class B1. Compositional state characteristics: composition / diversity of ecological communities at a given location and time (e.g., presence / abundance of key species, diversity of relevant species groups)
Class B2. Structural state characteristics: aggregate properties (e.g., mass, density) of the whole ecosystem or its main biotic components (e.g., total biomass, canopy coverage, annual maximum normalized difference vegetation index (NDVI))
Class B3. Functional state characteristics: summary statistics (e.g., frequency, intensity) of the biological, chemical, and physical interactions between the main ecosystem compartments (e.g., primary productivity, community age, disturbance frequency)
Group C: Landscape level characteristics
Class C1. Landscape and seascape characteristics: metrics describing mosaics of ecosystem types at coarse (landscape, seascape) spatial scales (e.g., landscape diversity, connectivity, fragmentation)

5.33 The class **physical state characteristics** (A1) includes the physical descriptors of the abiotic components of the ecosystem (soil, water, air). Physical stocks (e.g., water table level, impervious surfaces) that may be subject to degradation due to human pressures are relevant choices, as they are sensitive to change, and relevant for policy interpretation. This class thus also includes variables concerning extreme temperature, rainfall or drought events linked to climate change.

5.34 The class **chemical state characteristics** (A2) includes descriptors of the chemical composition of the abiotic ecosystem components. This typically involves a focus on the accumulated stocks of pollutants or nutrients in soil, water, or air. Similar to *physical state characteristics*, indicators should describe the state ("stocks" of pollutants) rather than the flows (emission of pollutants), i.e., the stock variables should be sensitive to changes in the flows.

5.35 The class **compositional state characteristics** (B1) includes a broad range of 'typical' biodiversity characteristics which describe the composition of ecological communities from a biotic perspective. This includes characteristics such as the presence / abundance of a species or taxonomic group, or the diversity of specific groups at a given location and time. From a location-based perspective (required for spatial consistency), the distribution of a species also reflects species composition (local presence). Compositional characteristics can thus concern the presence / absence or abundance of individual species, taxonomic groups (birds, butterflies, provenance of a species), or non-taxonomic guilds (e.g., soil invertebrates, macro-zoobenthos). Characteristics that concern specific functional groups (e.g., pollinators, nitrogen fixers, predators, decomposers, etc.) should be considered as *functional state characteristics*. Abundance characteristics of very large guilds (e.g., trees, phytoplankton) comprising entire ecosystem compartments should be considered as *structural state characteristics* (biomass, vegetation).[47]

5.36 The class **structural state characteristics** (B2) includes characteristics primarily focused at the vegetation and biomass of ecosystems that describe the local amount of living and dead plant matter (vegetation, biomass). This class includes all characteristics concerning vegetation density and cover, either related to the whole ecosystem, or just specific compartments (e.g., canopy layer, belowground biomass, litter). For marine and freshwater ecosystems this class can include phytoplankton abundance, or plant biomass (e.g., seagrasses). There is some overlap between *compositional* and *structural* state characteristics, particularly for ecosystem types based on individual, foundation species, such as mangroves, or where species groups and vegetation compartments coincide (e.g., trees on savanna, lichens on mountain rocks). Where overlap occurs, such cases should be registered in this class (structural).

5.37 The class **functional state characteristics** (B3) includes characteristics about relevant ecosystem processes (e.g., frequency, intensity) which are not already covered by other indicators. Therefore, information about the state of specific functional groups of species which perform ecosystem functions (e.g., producers, pollinators, nitrogen fixers, predators, decomposers, etc.) could be included here. Ecosystem functions is a diverse umbrella concept, which is used in different ways by the various research communities (Pettorelli et al., 2018). Many of the characteristics that can be seen as ‘ecosystem functions’ can also be seen as a compositional (e.g., species abundances), structural (e.g., plant biomass), or abiotic state descriptors (e.g., surface albedo). It is good practice to avoid placing functional characteristics into this class if they can be readily included in another class.

5.38 The class **landscape and seascape characteristics** (C1) includes characteristics of ecosystem assets that are quantifiable at larger (landscape, seascape) spatial scales but that have an influence on the local condition of ecosystems and can be attributed to individual ecosystem assets. Examples are metrics that quantify how an ecosystem asset is connected to other ecosystem assets of the same ecosystem type, how close ecosystem assets are situated from certain pressures, such as intensive agriculture, or how the condition is influenced by other assets, for instance, in measuring the condition of ecosystem assets that are part of a river network. There is in principle no limit to the distance that should be considered when assessing landscape and seascape characteristics as long as this distance does not fall outside the EAA.

5.39 Metrics of connectivity and fragmentation focus on important landscape and seascape characteristics from the perspective of a specific ecosystem type (or group of ecosystem types), for example the fragmentation of a forested areas by agricultural activities. Landscape and seascape connectivity can be interpreted and measured very differently in terrestrial, freshwater, and marine biomes. In the case of ecosystem assets which themselves are ‘mosaics’ of various ecosystem types (e.g., a cropland with nested semi-natural vegetation fragments), indicators of the abundance or the spatial pattern (connectivity) of the ecosystem types can also be hosted under this class.

[47] Note that in using biodiversity characteristics to describe the composition of an ecosystem asset, it should not be inferred that this is sufficient information to describe completely the related concept of species composition which will require additional information concerning the links between an individual species and wider spatial scales.

5.40 Chapters 3 and 4 highlighted the important distinction between ecosystem types whose ecosystem processes are primarily naturally driven and those ecosystem types that are more directly influenced by intensive human activity and management (anthropogenic ecosystem types). This distinction is also important in the measurement of ecosystem condition. The ECT applies to all ecosystem types but it is noted that there is likely more similarity among the characteristics selected for natural and semi-natural ecosystem types compared to those selected for assessing the condition of anthropogenic ecosystem types.

5.2.4 Ecosystem condition variables and their selection

5.41 ***Ecosystem condition variables are quantitative metrics describing individual characteristics of an ecosystem asset.*** A single characteristic can have several associated variables, which may be complementary or overlapping. Variables differ from characteristics (even if the same descriptor is applied to them) as they have a clear and unambiguous definition (measurement instructions, formulae, etc.) and well-defined measurement units that indicate the quantity or quality they measure. Examples of variables are the number of bird species, tree coverage (%) and turbidity (nephelometric turbidity unit, NTU).

5.42 Generally, selection of variables should prioritise those that reflect a role in ecosystem processes, and hence contribute to whole-ecosystem functioning, and their risk of change (Mace, 2019). Environmental variables should reflect stocks rather than the connected flows, which are often more obvious and observed as pressures or degradation processes. Examples of variables as stocks that are appropriate as measured variables include the thickness of the soil layer, concentration of pollutants, or abundance of invasive species. These may be considered as renewable or degradable stocks. Variables selected to reflect ecological processes can include the presence, abundance, or diversity of species with specific biological attributes that reflect interactions within the ecosystem. Classifications of functionally equivalent species based on sets of traits, described in terms of their response to environmental factors, provide useful metrics of biodiversity and the relationship with ecosystem integrity (Cernansky, 2017; Lavorel et al., 1997). Examples of variables include fruit-eating species that disperse seeds, nectar-eating species that pollinate, decomposer organisms, and canopy emergent species that provide habitat for epiphytes.

5.43 Variables used to measure ecosystem condition are those that are likely to change because of human interventions. However, many ecological processes and their responses to human or environmental impacts are complex, and hence response functions of variables may be non-linear. For example, excess nutrients running off from cropland into a shallow lake can cause a sudden ecosystem response where the system flips from a stable clear state into a stable turbid state. The form of these responses can be quantified and interpreted based on understanding of the ecological processes.

5.44 Selection criteria should be used to guide the identification of variables (Czúcz et al., 2021b). Variables that are superior with respect to the selection criteria, for example that are more sensitive to change, should be preferred for inclusion within an ecosystem condition account. The twelve criteria listed in Annex 5.1 provide a basis for selection. The first ten criteria are decisive as to whether a specific variable (and/or the underlying characteristic) is eligible for inclusion in the ecosystem condition accounts. The last two criteria ensure that the set of variables represents the state of the ecosystem in a meaningful way.

5.45 Altogether, condition accounts should cover as much relevant ecological information as possible, but parsimoniously, i.e., using as few variables as possible. It is not expected that the measurement of condition would require the inclusion of a vast number of characteristics and variables. From an ecosystem accounting perspective, the aim is to provide a broad indication of the change in condition rather than to fully map the functions of every ecosystem asset.

5.46 The most appropriate breadth and detail of variables selected to characterize ecosystem condition is difficult to standardize given the range of ecosystem types and differences across countries. The ECT, together with their criteria for selection, supports adoption of a pragmatic and structured approach that can be applied in all circumstances and can encompass measurement at a range of scales. Ideally, the compilation of ecosystem condition accounts should ensure that for each ecosystem type, at least one variable is selected for each of the six ECT classes. This rule of thumb aims to ensure a minimum level of comprehensiveness in the full set of condition variables.

5.47 Based on evaluation of examples of existing ecosystem condition accounts, a set of around six to ten well-selected indicators for a given ecosystem type should provide sufficient information to assess the overall condition of an ecosystem asset. In practice, it is important to incorporate knowledge of local ecosystems. The selection of variables and metrics should be based on existing ecological knowledge and monitoring systems, with ecologists directly involved in the selection process.

5.2.5 Ecosystem condition variable account

5.48 The structure of the ecosystem condition variable account is shown in Table 5.2 where opening and closing entries are recorded for selected variables for an ecosystem type. The variables are grouped based on the ECT.

5.49 The initial focus on variables provides a structured system for recording data on ecosystem condition. In particular, the use of standard classes of ecosystem types allows clear connections to be drawn to measures of ecosystem extent and flows of ecosystem services that are organised using the same classes.

5.50 Particular emphasis should be placed on the definition and documentation of variables and metrics included in the account since it is common for a single descriptor to be used for related but different variables. The documentation should contain enough information for scientific reproducibility, it should be unambiguously linked to the short names used in the variable and indicator accounts and it should be able to be communicated effectively to users of the accounts.

5.51 Data in ecosystem condition variable accounts can provide useful information about the state of an ecosystem and its change over time. For example, measurement of soil pH is a variable that is sensitive to change due to human land management and monitoring this change, irrespective of a reference level, is useful to report in a condition account to demonstrate changes in soil properties due to human impacts or changing environmental factors.

5.52 The condition variable account can also be used to compare observed measurements of certain variables to information about critical ecosystem thresholds, for example from scientific studies or fisheries management work. For example, freshwater pH values indicate clearly whether biological life is feasible in a given water body, soil nutrient enrichment above a certain level will lead to the extinction of sensitive species and the age structure of a fish population can be a good indication of whether it is being exploited at a sustainable yield level or beyond. The condition variable account can also be used for a direct comparison with politically determined target values, for example, relating to species richness or (bathing) water quality.

Table 5.2: Ecosystem condition variable account

SEEA Ecosystem Condition Typology Class	Variables		Ecosystem type		
	Descriptor	Measurement unit	Opening value	Closing value	Change
Physical state	Variable 1				
	Variable 2				
Chemical state	Variable 3				
Compositional state	Variable 4				
	Variable 5				
Structural state	Variable 6				
Functional state	Variable 7				
Landscape/seascape characteristics	Variable 8				

5.53 The recording of variables in this account reflects an explicitly neutral approach since each entry is not compared to a baseline and there is no implied judgement of relative importance, for example, entries cannot be interpreted as being high, medium or low. Since there is no information incorporated in the account to interpret the data, the use of the data in this account should focus on monitoring and reporting change in variables over time. Thus, the information will support the preparation of indicators that describe changes in ecosystem condition.

5.54 In an EAA, the many ecosystem assets that comprise each ecosystem type can each have different values for the variables describing condition. This spatial variation is caused by spatially explicit patterns of pressures on ecosystems, ecosystem management, or characteristics that shape ecosystems such as slope and elevation. To take the spatially explicit character of ecosystem condition into account, the values recorded in an ecosystem condition variable account should be calculated as the area weighted arithmetic mean of ecosystem assets belonging to the particular ecosystem type within the EAA. Other statistical moments (e.g., variance, median, minimum, maximum values, or the number or area of ecosystem assets with a value above a certain threshold) can also be recorded if considered useful. Area weighted averaging results in a condition variable account that describes the average values of variables for an ecosystem type within an EAA. It follows that if the variable values for one or more assets changes between accounting periods, the average value for the ecosystem type will also change.

5.55 Qualitative variables or measures such as species presence or water quality that are measured on an ordinal scale from low to high can be used as well. For these variables, the account records the relative share of one of the classes over the entire EAA (e.g., the percentage of ecosystem assets where a species is present).

5.56 The common temporal units for aggregation in accounting are years. However, data will not all pertain to the same point in time or period depending on the variable. In addition, data are collected at different temporal resolutions spanning from seconds or days (e.g., air quality measurements) to weeks, months or seasons (e.g., productivity measurements from earth observation), to years or multiple years (land cover changes, species records). Bringing these observations to a common temporal unit or a common reporting year can be done using the following methods. Temporal aggregation means summing or averaging values taken within a time period (for instance one year). Linear interpolation can be used to calculate a value for a specific year for which no measurement data are available based on the values of the preceding and following years for which data are available. Recording smoothed data in the condition account for instance by taking a moving average over several time periods can be appropriate to track the trends of highly dynamic ecosystem variables and to compare them with trends obtained for less dynamic variables.

5.57 Care should be taken when variables are added directly to the condition account at the ET or EAA level since they do not necessarily capture the average condition of an ecosystem type derived from the variation over the ecosystem assets. An example is the total number of species observed in an ecosystem type within an EAA (also known as gamma diversity). While species richness of an EAA is an important variable in understanding the state of biodiversity, it might be less appropriate when quantifying the ecosystem condition of a specific ecosystem type. Thus, where species richness is used as ecosystem condition variable, it is more appropriate to measure local species richness of different ecosystem assets and report the average species richness in the compilation of a condition account.

5.58 In practice, many data are available at an aggregated level for EAA, for instance data based on the range or distribution of species or globally used indices such a Living Planet Index or the Ocean Health Index.[48] These data may appear to lend themselves to being directly included in an ecosystem condition account but care is needed to ensure consistency between the spatial scale used in their measurement and the spatial scale used for other variables. Ideally, all data should be able to be attributed to the ecosystem asset level.

5.59 There is a wide array of potential data sources at global, national and local levels. From a statistical perspective, relevant data may be available within the context of the Framework for the Development of Environmental Statistics (FDES) and the associated Basic Set of Environment Statistics (BSES) (United Nations, 2017).

5.3 Ecosystem condition indicators

5.3.1 Deriving ecosystem condition indicators from variables

5.60 ***Ecosystem condition indicators are rescaled versions of ecosystem condition variables***. They are derived when condition variables are set against reference levels determined with respect to ecosystem integrity. Two steps are involved. First, data values for each variable are transformed to a common dimensionless scale, with the two endpoints of the scale (or a range along the scale) representing a top value (1 or 100%) and a bottom value (0 or 0%) for that variable. It is important to note that while in some cases the top values for a variable can also reflect a high condition score, the opposite is also possible, i.e., bottom values for a variable can reflect a high condition score, for instance for variables that measure pollution levels.

5.61 Second, the transformed data are converted to ecosystem indicators. The simplest conversion uses two reference levels to reflect a high or low condition score. In this case, the indicator is calculated by a linear transformation shown in the formula below.

$$I = (V - V_L) / (V_H - V_L)$$

where I is the value of the indicator, V is the value of the variable, V_H is the high condition score and V_L is the low condition score.

5.62 Other types of rescaling functions can be used but may not be appropriate for all metrics, such as those including both positive and negative numbers, and hence should be clearly documented and justified. Values of variables should be transformed such that the upper reference level is higher than the lower one to ensure that the direction of the scale for indicators is consistent. For example, the high reference level of a pollutant may equate to a variable value of zero since this represents a high level of condition. This way of rescaling ensures that higher indicator values are always associated with a higher condition, even if the scale of the original variable was the opposite. Rarely, there might be cases when the observed value of the variable is out of the range of the two reference levels, for example

[48] See https://www.livingplanetindex.org/home/index and http://www.oceanhealthindex.org/.

above the high reference level. In these cases, it is recommended that the values of the indicator be truncated at 0 (0%) or 1 (100%) (Paracchini et al., 2011).

5.63 Applying a reference level converts that variable from being a measure of trends in ecosystem characteristics to an assessment of ecosystem condition in relation to a reference. Such normalization adds value in the interpretation of trends and is also required by any later aggregation steps, which need commensurate metrics measured on the same scale using common units (Nardo et al., 2005).

5.64 A set of indicators for a condition account can include some common or global indicators in addition to indicators specific to an ecosystem type. Examples of indicators are presented in section 5.5.1.

5.3.2 Reference levels

5.65 ***A reference level is the value of a variable at the reference condition, against which it is meaningful to compare past, present or future measured values of the variable.*** The difference between the value of a variable and its reference level represents the distance from the reference condition. Following the steps outlined above, the value of the reference level is used to re-scale a variable to derive an individual condition indicator. Reference levels are defined in a structured and consistent manner across different variables within an ecosystem type, and for the same variable across different ecosystem types. This ensures that the derived indicators are compatible and comparable, and that their aggregation is ecologically meaningful.

5.66 Reference levels are usually set with high and low levels reflecting the limits or endpoints of the range of a condition variable that can be used in re-scaling. For example, the high level may refer to a natural state and the low level may refer to a degraded state where ecosystem processes are below a threshold for maintaining function (such as ecosystem collapse; (D. A. Keith et al., 2013)). One of the reference levels can often be replaced by the natural zero value of the variable, for example zero abundance (local extinction) for a species, or the lack of a specific pollutant. Reference levels applied to the same variables are likely to differ for different ecosystem types. For example, using the normalized difference vegetation index (NDVI) to measure the variable of biomass quantity will require different reference levels for forest, savannah and grassland ecosystems.

5.67 Individual reference levels can be set once a reference condition is selected. Different methods are available to establish a reference condition and to assign values for the reference levels of ecosystem condition variables (see Annex 5.2 for strengths and weaknesses of these methods).

5.68 Different reference levels can be set depending on the purpose of an individual indicator. As a result, different indicators may be derived from the same variable within the same ecosystem. For the measurement of ecosystem condition in the SEEA EA, the purpose is to measure ecosystem integrity and for this purpose the reference level should be established in relation to a common reference condition as described below.

5.3.3 Reference condition

5.69 ***A reference condition is the condition against which past, present and future ecosystem condition is compared to in order to measure relative change over time.*** It represents the condition of an ecosystem that is used for setting the high level (or one endpoint) of reference levels of the variables that reflect high ecosystem integrity. The reference condition corresponds to a state where all condition indicators have a (spatially averaged) value of 1 (100%). The best way to ensure the consistency of reference levels for different variables describing the same ecosystem asset is to start from a single reference condition. Using the concept of reference condition, the condition of an ecosystem asset is measured in terms of the distance between its current condition and its reference condition.

5.70 For ecosystem accounting purposes, the reference condition is based on the principle of maintaining ecosystem integrity, stability and resilience (over ecological timeframes).[49] In many ecosystem types, it refers best to the natural state (i.e., the ecological state of a natural ecosystem), in terms of ecosystem characteristics at their natural condition while allowing for dynamic ranges. The metrics of condition represent the distance from natural irrespective of the characteristic, ecosystem type, or potential desired outcome from a human perspective. The reference condition of an ecosystem corresponds to the condition where the structure, composition and function are dominated by natural ecological and evolutionary processes including food chains, species populations, nutrient and hydrological cycles, self-regeneration and involving dynamic equilibria in response to natural disturbance regimes. An ecosystem at a natural reference condition exhibits an absence of major human modification. An ecosystem at its reference condition attains maximum ecosystem integrity (Gibbons et al., 2008; Mackey et al., 2015; Palmer & Febria, 2012).

5.71 Using the natural state as the reference condition allows recognition of the characteristics of the natural state and change from the natural state to be reflected in ecosystem accounts. The natural state may not be related to supply of ecosystem services and may not be the target of current legislation, policy or ecosystem management objectives. However, measuring condition relative to the natural state provides an important means of understanding the degree of ecosystem change that has taken place, as well as supporting the assessment of many environmental policies and associated objectives concerning conservation values.

5.72 Using the natural state as the reference condition is preferred and recommended. However, in many cases, it may not be possible to define a reference condition as 'natural' in absolute terms, since the environment may have changed due to both human and natural processes. In cases where a natural state does not represent a meaningful reference for condition accounts, particularly for anthropogenic ecosystems under varying degrees of cultivation (such as cropland, pastures and managed forests) and urban ecosystems, alternative reference conditions, still characterised by integrity, stability and resilience, can be established and considered as anthropogenically-derived reference conditions.

5.73 Based on a common principle for defining reference conditions, a range of methodological options may be used for establishing reference conditions given the differences in ecosystem types, disturbance regimes and data availability. Annex 5.2 presents an assessment framework that can help distinguish between natural and anthropogenic ecosystem states and it summarises the possible approaches for selecting a reference condition. Reference conditions, and their associated reference levels, can be difficult to determine appropriately and explicitly, and describing the rationale for their selection and their links to the purpose of the accounts is important.

5.74 In setting reference conditions, since both the timespan and extent of human influence has varied in different parts of the world, assigning a date in time as the reference condition is problematic. For example, variation has occurred in the time of human settlement,

[49] Many related meanings have been assigned to reference condition for different purposes related to varying levels of human disturbance, where each refer to specific types of assessments. Annex 5.2 provides an explanation of the various alternative assessment frameworks for reference condition and associated approaches to measurement.

development of agriculture, hunting, domestication of livestock, use of fire to influence vegetation structure and composition, major land clearing and intensive production. More generally, using inconsistent reference conditions across ecosystem types will prevent meaningful comparisons, and individual years may be subject to considerable variability and inconsistency due to ecosystem dynamics.

5.75 Developing reference conditions to assess changes in ecosystem condition is important to support international conventions. The selection of a reference condition should be applied as consistently as possible across the different realms (terrestrial, freshwater, subterranean and marine), biomes and ecosystem functional groups. Globally agreed reference conditions are useful to support global comparisons, for instance to evaluate individual country commitments towards ecosystem maintenance and restoration, for examples see H. Keith et al. (2020). However, some of these reference conditions may incorporate aspects concerning policy targets and hence may not fully reflect the conceptual basis for a reference condition for ecosystem accounting purposes.

5.3.4 Ecosystem condition indicator account

5.76 The structure of the ecosystem condition indicator account (Table 5.3) builds directly on the ecosystem condition variable account (Table 5.2) by relating each variable to a reference level. Each variable is rescaled (transformed) to a uniform dimensionless scale [0, 1] using its reference level. The data in the indicator account allows descriptions of trends in condition to be interpreted relative to an agreed reference condition based on ecosystem integrity. This allows for statements concerning whether, for a given variable, ecosystem condition can be considered high (close to the reference level) or low (distant from the reference level). The indicator account can be used to monitor and report change in values over time.

5.77 Among the set of ecosystem accounts, the ecosystem condition indicator account is a key output. In a structured way, it organises key ecological data in a manner that allows comprehensive reporting on the ecosystem integrity of the ecosystems within an ecosystem accounting area across a range of ecosystem characteristics. Regular reporting of an ecosystem condition indicator account that tracks trends using a number of relevant indicators is intended to support an extensive, and ecologically informed, discussion of both the effectiveness of strategies aimed at improving ecosystem condition and the changing capacity of ecosystems to supply ecosystem services. There is not a direct, linear relationship between changes in ecosystem condition and changes in ecosystem capacity. Accounting for condition therefore provides a structured framework for collating data to analyse this relationship in combination with data on flows of ecosystem services as described in Chapter 6. Chapter 6 also defines the concept of ecosystem capacity and describes ways in which its measurement may be considered.

5.78 The data from the ecosystem condition indicator account will also underpin the derivation of composite indices of ecosystem condition. Such indices may be of considerable power in conveying general messages around changes in ecosystem condition. A number of different aggregations of indicators from a single ecosystem condition indicator account are possible following different approaches to aggregation. Those approaches and relevant assumptions are discussed in section 5.4. Irrespective of the approach to aggregation that is applied, it remains appropriate to compile an ecosystem condition indicator account such that the summary messages of the composite indices can be appropriately interpreted and understood.

Table 5.3: Ecosystem condition indicator account

SEEA Ecosystem Condition Typology Class	Indicators	Measure ment unit	Ecosystem type						
			Variable values		Reference level values		Indicator values (rescaled)		
	Descriptor		Opening value	Closing value	Upper level (e.g., natural)	Lower level (e.g., collapse)	Opening value	Closing value	Change in indicator
Physical state	Indicator 1								
	Indicator 2								
Chemical state	Indicator 3								
Compositional state	Indicator 4								
	Indicator 5								
Structural state	Indicator 6								
Functional state	Indicator 7								
Landscape/seascape characteristics	Indicator 8								

5.4 Aggregate measures of ecosystem condition

5.4.1 Ecosystem condition indices

5.79 The derivation of aggregate ecosystem condition indices is possible where there is interest is reporting on ecosystem condition at higher levels of aggregation than presented in the ecosystem condition indicator account. The aggregation of ecosystem condition indicators aims to generate summarized information from a large number of data points. This can be useful in order to communicate general trends. At the same time, aggregation of a variety of indicators can conceal important information present in individual indicators and hence aggregate indices require careful interpretation, particularly where individual component indicators show opposite trends. Thus, within the SEEA EA, the derivation of condition indices is optional and, where it is undertaken, a clear link should be made to information on movements in individual indicators as described in stage two.

5.80 The hierarchical approach to aggregation reflects the structure of the typology of the indicator classification. First aggregated sub-indices are derived from the indicators, and then an aggregated index is derived from the sub-indices. Hierarchical aggregation schemes should also contain a description about how missing indicators or sub-indices are handled. The hierarchical structure means that indices should be scalable across spatial resolutions.

5.81 ***Ecosystem condition indices and sub-indices are composite indicators that are aggregated from the combination of individual ecosystem condition indicators recorded in the ecosystem condition indicator account.*** The aggregation process is underpinned by using compatible reference levels from a common reference condition. Thus, component indicators are scaled according to their reference levels, normalised to a common scale and direction of change, and combined to form a composite index. The use of a typology for indicators and an appropriate aggregation scheme allows derivation of various sub-indices and overall condition indices. General guidance on the derivation of these measures can be found in, for example, Andreasen et al. (2001); Buckland et al. (2005); Burgass et al. (2017); OECD (2008); Van Strien et al. (2012).

5.82 The structure of ecosystem condition accounting described in this chapter allows for aggregation in several ways. For example, aggregation is possible across indicators within the same ECT class, across classes of characteristics in the ecosystem condition typology, or across ecosystem types. Thus, sub-indices derived through aggregation can relate to specific typology classes (e.g., structural state of temperate woodlands) or ecosystem types (e.g., an ecosystem condition index for rivers).

5.83 An example is creation of an overall ecosystem condition index where the aggregation can take the form of a condition index applied to each ecosystem type, weighted by the area of the ecosystem type within the ecosystem accounting area, then summed for all ecosystem types in the ecosystem accounting area to derive an overall ecosystem condition index (Brink, 2007; Czúcz et al., 2012).

5.84 Aggregation requires expert opinion in selecting groups of indicators and mathematical methods for the aggregation based on an ecological understanding of the ecosystems, and a clearly defined purpose for the resultant index. Data for individual variables or indicators should be preserved in a disaggregated form and at as high a resolution as possible within the information system. Consequently, aggregation is the last step in the analysis, and it should be possible to scale up and down and across at different scales depending on the purpose and form of analysis.

5.85 Aggregation has both thematic and spatial aspects. The basic thematic units are the ecosystem condition indicators, which are dimensionless and have a common scale. The indicators can be combined according to the ECT classes and groups. Within each ecosystem type there is a different list of relevant indicators, but the typology classes and groups are the same for all ecosystem types. Accordingly, the relevant levels of thematic resolution are the indicators, sub-indices (condition of typology classes or groups within an ecosystem type); indices (condition of an ecosystem type in an ecosystem accounting area), and overall indices (overall condition of multiple ecosystem types in an ecosystem accounting area).

5.86 Thematic aggregation assumes that different indicators can compensate for each other, depending on the structure of the index. Consider two forest condition indicators: the number of forest bird species and the amount of dead wood. Increasing values of both indicators are associated with increasing condition. Both indicators can, however, have different directions of change, for example, forest bird numbers may be declining but dead wood quantities may be increasing. In this case, thematic aggregation might lead to the conclusion that the forest condition remains stable and hence additional ecological interpretation is likely to be needed to confirm such an assessment.

5.87 Spatial aggregation involves aggregation across ecosystem types. Care is required in this kind of aggregation as some ecosystem types are fundamentally different and so aggregation across them may not always be meaningful. Aggregation across ecosystem types from different realms (e.g., marine and terrestrial) or with different reference conditions (natural or anthropogenic) is not recommended. Aggregation should be confined to ecosystem types that have the same reference condition so that the increases and decreases in condition of each group can be identified.

5.88 The common temporal units for aggregation in accounting are years. However, temporal aggregation can be done at different periodicities depending on the purpose and other information to which it is related, for example financial year for economic data, or growing seasons for plants.

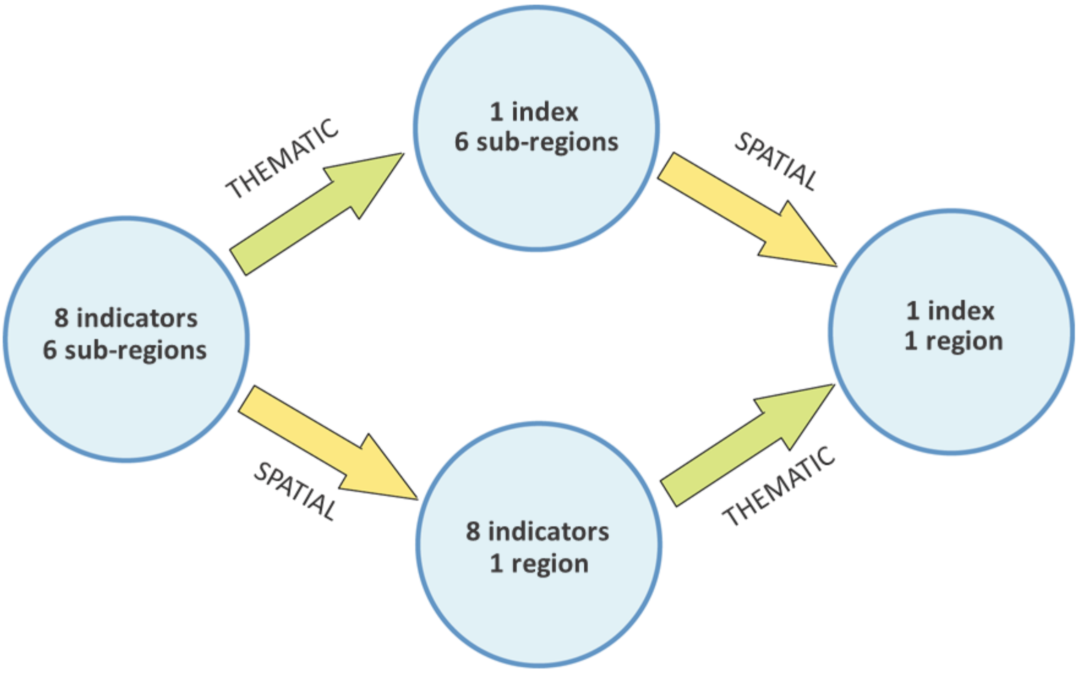
5.89 The approaches to spatial aggregation described here involved aggregation of variables that are meaningful at the level of individual ecosystem assets. The resulting aggregate indicators are therefore average measures of condition reflecting the condition of the constituent ecosystem assets.

5.90 Biotic ecosystem characteristics, and their associated variables and indicators, have metrics at a range of scales from local to global. Quantitative assessment of biodiversity across these scales is imperfectly nested, and hence cannot always be upscaled or aggregated simply. Several biodiversity indicators only emerge at broad (national, continental) spatial scales and cannot be produced as “sums” of smaller parts (e.g., the beta diversity of large areas). Hence, for some purposes, in particular for aggregate measures of biodiversity, it will be appropriate to also incorporate data on variables at a range of scales as described in the previous paragraph. Relevant considerations are discussed further in section 5.5.4.

5.4.2 Potential aggregation functions and weights

5.91 Aggregation functions and weights are used in various forms in each type of aggregation operation. Ideally, aggregation operations should be commutative, i.e., subsequent operations should lead to the same result irrespective of the order in which these operations are performed (Figure 5.1).

Figure 5.1: Aggregation commutativity: subsequent aggregation operations result in the same aggregated values, no matter the order of the operations.



5.92 In principle there are several choices for aggregation functions for each type of aggregation operation that can be distinguished, depending on the purpose of the index. The range of types of functions used to calculate central tendency include arithmetic mean, geometric mean, minimum and maximum operators, quantiles and median. The arithmetic mean is the most commonly used function, but the geometric mean and harmonic mean have more sensitivity to low values and to skewed distributions. Hence, the geometric mean is often used in environmental science for describing statistics associated with variables that tend to vary in space or vary by several orders of magnitude. Minimum or maximum operator or threshold detection approaches are often used to recognize the importance of the lowest values or poorest condition of an indicator, or alternatively the highest values or best condition of an indicator. The one out - all out approach, where the condition index is based on the lowest value indicator, is a special case of using the minimum function as the central tendency.[50]

[50] This approach has been applied for the derivation of SDG indicator 15.3.1 on land degradation.

5.93 The selection of a weighting system depends on the relative importance of each indicator to an assessed overall condition of the ecosystem. The approach to weighting should have a scientific rationale and incorporate the input from ecologists with expertise in the specific ecosystem types. For spatial aggregation, area-weighted sums and means are a typically good choice. Equal weighting assumes equal importance, and while this is the most common approach for thematic aggregation, equal importance may not necessarily be true across all indicators. Non-equal weighting may be appropriate if there is an imbalance in availability of indicators (e.g., some characteristics are represented with more indicators than others), or when the different characteristics, measured by their respective indicators, play relatively different roles from an ecological perspective. Relationships between characteristics may be non-linear and different thresholds may apply.

5.94 The selection of methods for the aggregation of condition metrics derived for individual spatial units should consider the landscape context (e.g., the configuration of ecosystem assets within a catchment) and the derivation of representative mean and range in condition. In some cases of aggregation, a combination of approaches of functions and weightings are appropriate for different indicators associated with threshold effects or differing relative importance. Methods for weighting and normalizing scores can be complex and influence the outputs. Therefore, documentation and explanation of the assumptions is important and the applicability of aggregated indices across characteristics or ecosystem types should be tested.[51]

5.95 Many of the options for aggregation are widely used in established environmental indicator frameworks. For example, the Human Development Index applies arithmetic means for sub-indices, followed by a geometric mean for the overall index. A 'precautionary' one out - all out approach (where a single declining indicator means a decline in condition whereas improvement is based on an ensemble of increasing indicators) is used in the assessment of the conservation status linked to the European Union Habitats and Birds Directives and the IUCN Red List of Species and the IUCN Red List of Ecosystems. Nevertheless, neither the purpose nor the data types of these aggregation framework match those of the SEEA EA condition accounts. Further scientific studies should explore the advantages and disadvantages of particular aggregation strategies (i.e., combinations of aggregation functions and weighting schemes for the various aggregation dimensions) including consideration of dealing with uncertainties in measurement.

5.4.3 Presentation of ecosystem condition indices

5.96 As described above, as required, it is possible to aggregate ecosystem condition indicators to form sub-indices according to the ECT classes both within ecosystem types and across different ecosystem types. Aggregation of indicators requires scaling/normalisation of indicator values against a single reference condition for the ecosystem type, so that different variables and classes of characteristics can be compared. Aggregated sub-indices and indices have the same range and direction as the indicators, for example [0 – 1]. An aggregated sub-index is derived for each class in the ecosystem condition typology that provides a composite measure from the combination of indicators that describe the same class in the typology for a given ecosystem type. An ecosystem condition index is derived from a second aggregation step using the sub-indices for each ecosystem type ('mean values' approach). Using stylized indicator values, Table 5.4 shows the derivation of various condition indices.

[51] Examples of the evaluation of indices include Andreasen et al. (2001); Buckland et al. (2005); Fulton et al. (2005); Rowland et al. (2020).

5.97 An alternative method for presenting data of the aggregate indices is recording the areas of each ecosystem type that is covered by various ranges of ecosystem condition relative to the reference condition. For example, an account for the ecosystem type of forests could show the total area of forest divided into low, medium or high condition areas. Area values can be reported in absolute terms (e.g., ha) or in relative terms (as a percentage of the total area). Different threshold scores can be used based on different methodologies to define the number of intervals and their range ('discretised ranges' approach). Using stylized indicator values and assumed areas, Table 5.5 shows the derivation of condition indices reflecting discretised ranges. The 'mean values' and the 'discretised ranges' approaches have both been used in existing condition accounts (Maes et al., 2020).

Table 5.4: Ecosystem condition indices reported using rescaled indicator values ('mean values' approach)

SEEA Ecosystem Condition Typology Class	**Indicators**	**Ecosystem type**				
		Indicator value			Index value	
	Descriptor	Opening value	Closing value	Indicator weight	Opening value	Closing value
Physical state	Indicator 1	0.5	0.25	0.05	0.025	0.013
	Indicator 2	0.9	0.7	0.05	0.045	0.035
	Sub-index				*0.07*	*0.048*
Chemical state	Indicator 3	0.625	0.5	0.1	0.063	0.05
Total Abiotic characteristics					0.133	0.098
Compositional state	Indicator 4	0.94	0.89	0.067	0.063	0.062
	Indicator 5	0.75	0.50	0.033	0.025	0.017
	Sub-index				*0.088*	*0.079*
Structural state	Indicator 6	0.5	0.25	0.12	0.06	0.03
Functional state	Indicator 7	1	0.66	0.08	0.08	0.053
Total Biotic characteristics					0.228	0.162
Landscape and seascape characteristics	Indicator 8	0.5	0.2	0.5	0.25	0.1
Ecosystem condition index	**Index**			**1.0**	**0.611**	**0.360**

Table 5.5: Ecosystem condition indices reported using discretised ranges (i.e., area (%) in each range of condition)

SEEA Ecosystem Condition Typology Class	**Indicators**		**Ecosystem type**					
	Descriptor	Indicator weight	Opening value			Closing value		
			High	Medium	Low	High	Medium	Low
Physical state	Indicator 1	0.05	10	80	10	5	45	50
	Indicator 2	0.05	70	25	5	60	20	20
	Sub-index		*40*	*52.5*	*7.5*	*32.5*	*32.5*	*35*
Chemical state	Indicator 3	0.1	30	40	30	20	50	30
Compositional state	Indicator 4	0.067	80	15	5	80	10	10
	Indicator 5	0.033	100	0	0	0	0	100
	Sub-index		*86.6*	*10.1*	*3.4*	*53.6*	*6.7*	*39.7*
Structural state	Indicator 6	0.12	30	30	40	10	20	70
Functional state	Indicator 7	0.08	100	0	0	50	30	20
Landscape and seascape characteristics	Indicator 8	0.5	30	30	40	20	20	60
Ecosystem condition index	**Index**	**1.0**	**42.2**	**28.9**	**28.9**	**25.8**	**23.7**	**50.5**

5.98 Table 5.4 and Table 5.5present the derivation of ecosystem condition indices for one ecosystem type. For presentational purposes, it may be appropriate to summarise the results for a number of ecosystem types in one table. Table 5.6 shows such a structure allowing for the recording of opening and closing condition values and changes in those values due to changes in the component characteristics. A total across ecosystem types is not shown as this would require aggregation across ecosystem types that apply different reference conditions and this is not recommended. Further, due to the use of different reference conditions for different ecosystem types, care should be taken in comparing the condition scores across ecosystem types.

Table 5.6: Ecosystem condition account (condition indices) for multiple ecosystem types

	Stylized ecosystem types					
Accounting entries	Forests	Lakes	Cropland	Urban areas	Wetlands	Seagrass
Opening condition value						
Change in abiotic ecosystem characteristics (physical and chemical state)						
Change in biotic ecosystem characteristics (composition, structure and function)						
Change in landscape/seascape characteristics						
Net change in condition						
Closing condition value						

5.5 Considerations in the measurement of ecosystem condition

5.5.1 Introduction

5.99 The three-stage approach to accounting for ecosystem condition provides an appropriate structure for measurement. Nonetheless, there are a range of considerations and issues that will affect measurement in practice. This section discusses these issues.

5.5.2 Variables for selected ecosystem types

5.100 Following the approach described above, the measurement of ecosystem condition requires the selection of variables covering relevant ecosystem characteristics for different ecosystem types. The general principles and criteria for the selection of variables have been outlined in section 5.2 and by Czúcz et al. (2021b). In this section, a short summary is provided of considerations in variable selections for a number of key ecosystem types. As noted above, in practice, it is important that ecologists and related specialists with knowledge of the ecosystem types concerned are involved in the process of variable selection, as well as in the determination of reference conditions and levels.

5.101 An indicative selection of variables is presented in Table 5.7. The table shows possible variables for selected biomes and functional groups (following IUCN GET) and according to the classes of the ECT. The physical state variables mostly consider changes in water content and soil for terrestrial ecosystems and water clarity for aquatic ecosystems. Chemical state variables include pH, soil organic carbon content and concentrations of nutrients and pollutants. The compositional state can be measured using the diversity of various taxa such as tree species, birds, reptiles, fish, or macro-invertebrates. Clearly, other species or taxa can be used as well to measure the condition of ecosystems. The structural state variables often relate to vegetation cover or specific aspects thereof. Functional state variables express to ecosystem characteristics such as productivity or decomposition processes. In a few cases, Table 5.7 explicitly mentions these characteristics to clarify the relationship with the selected variable.

5.102 The selections shown are not exhaustive and are not intended to reflect definitive measurement guidance for the selection of variables. In the first instance it is expected that local context will be considered in the selection of variables, i.e., that the measurement of ecosystem condition will be grounded in specific ecological knowledge and expertise. Of particular relevance in this regard will be knowledge of the underlying ecosystem functional groups and more detailed sub-types and their composition within a country or region. In this regard, the table should provide the basis for a structured conversation between account compilers and local experts.

5.103 Second, the descriptors in the table refer to a mix of variables and data sources. These examples are given as an indication of the potential for measurement. However, in practice, the selection of variables and indicators will require careful consideration to ensure their appropriate interpretation, for example concerning directionality. Additional guidance on the selection of variables and the collection of data will be developed.

5.104 Also concerning data, it should not be assumed that all data used for account compilation will be sourced from direct field observations. While this might be ideal, it is unrealistic. In practice, much data will be sourced from combining field observations with national environmental and statistical data and remote sensing, including satellite data.

Table 5.7: Examples of ecosystem condition variables for selected ecosystem types[52]

		A1 Physical state	A2 Chemical state	B1 Compositional state	B2 Structural state	B3 Functional state	C1 Landscape / seascape
T1	**Tropical-subtropical forests**	Soil water availability in the driest quarter; Wetness	Soil organic carbon content; Leaf and litter nitrogen concentration	Tree species richness; Bird species richness	Tree cover density; Dominant tree height; Number of canopy layers; Deadwood volume; Forest age class distribution; Density of epiphytes	Dry matter productivity; Presence of seed dispersing species (capacity for regeneration); Water stress index	Forest area density; Landscape diversity; Forest connectivity; Ratio of edge distance to interior area of forest patches
T2	**Temperate-boreal forests & woodlands biome**	Vegetation water content (NDWI)	Soil organic carbon content; Air pollutant concentration; Foliar and litter nitrogen concentration	Tree species richness; Lichen species richness; Bird species richness	Forest floor depth (soil layer thickness); Tree cover density; Deadwood volume; Forest age class distribution	Dry matter productivity; Density of trees with hollows for nesting; Presence of top predator species (food web functionality); Vegetation index (NDVI); Water stress index	Forest area density; Landscape diversity; Forest connectivity;
T3	**Shrublands & shrubby woodlands**	% Burnt area; Soil layer thickness	Soil organic carbon content; Soil phosphorus concentration	Bird species richness	Tree cover density	Dry matter productivity; Proportion of re-sprouting species after fire (capacity for regeneration)	Landscape diversity; Shrubland/forest connectivity
T4	**Savannas and grasslands**	% Bare ground	Soil organic carbon content; Soil pH	Bird species richness; Butterfly species richness; Proportion of non-native species	The presence/density of trees/shrubs	Dry matter productivity Abundance of termite mounds (organic matter turnover)	Connectivity of trees; Grassland connectivity
T5	**Deserts and semi- deserts**	Water availability; Degree of surface crusting	Soil pH	Reptile species diversity or abundance	Vegetation cover	Density of viable seeds in soil (capacity for regeneration)	Spatial distribution of waterholes
T6	**Polar-alpine (cryogenic)**	% Bare ground; Snow depth; Extent of sea ice	Pollutant concentrations	Lichen species richness	Vegetation cover; Lichen cover or abundance on rocks		Diversity of habitat types; Connectivity of routes for migratory species
T7.1	**Annual croplands**	Water holding capacity; Soil bulk density; Vegetation water content (NDWI)	Soil organic carbon content; Soil nutrient availability	Bird species richness	Share of organic farming; Crop diversity; Share of time or area as fallow land	Soil respiration rate (decomposition); Gross primary production	The presence/ share of semi-natural vegetation fragments (small woody features); Landscape diversity (mosaic)
T7.4	**Urban and**	Imperviousness	NO_2 concentration	Bird species richness	Share of urban green		Average distance of residents to

[52] This table is indicative only and is not intended to provide definitive measurement guidance for the selection of variables (or characteristics) in any given context. Ecosystem types are based on the IUCN GET (D. A. Keith et al., 2020). Variables are grouped following the SEEA Ecosystem condition typology. In some cases, the associated ecosystem characteristic is added in brackets.

	industrial ecosystems				space; Vegetation or tree cover		urban green space; Landscape diversity (mosaic)
TF1	**Palustrine wetlands**	Wetness; Surface water area; Water flow; Water holding capacity; Duration of water inundation/saturation	Nitrogen concentration Phosphorus concentration	Bird species richness; Dragonfly and damselfly species richness	Vegetation cover by native macrophytes	Biological oxygen demand	Landscape diversity; Wetland/water connectivity; Intensity of surrounding land use within a 50 m buffer area
F1	**Rivers and streams**	River flow (relative to ecological base flow); Permanence of water flow; Sediment load	Nitrogen concentration Phosphorus concentration;	Macro-invertebrate species richness	Area of riverbanks vegetated	Biological oxygen demand	Share of river flow controlled by barriers; Presence of anadromous fish; River system fragmentation
F2	**Lakes**	Water clarity; Water regime (permanence); Water flow; Sediment load	Nitrogen concentration Phosphorus concentration; Chlorophyll a concentration;	Fish species richness	Steepness of the water temperature depth profile (structure of the vertical profile of the lake); Ratio between biomass of predatory fish and total fish biomass; Ratio between zooplankton and phytoplankton	Biological oxygen demand; Ratio between productivity and biomass	Connectedness of riparian vegetation within the catchment; Share of lake shoreline with natural vegetation)
F3	**Artificial wetlands**	Water clarity	Nitrogen concentration Phosphorus concentration	Fish species richness	Steepness of the water temperature depth profile; Frequency and extent of algal blooms	% Area available as fish nursery	
M1	**Marine shelf**	Water clarity (turbidity); (Micro)plastic concentration	Chlorophyll a concentration; % Anoxic area; Oxygen concentration; pH (or dissolved CO_2)	Coral species richness; Fish species richness	Reef “bleachedness”; Kelp/seagrass height, density or cover; Live coral cover	Trophic composition number (food web functionality); Ratio between fishing mortality and fishing at maximum sustainable yield; Biological oxygen demand	Seagrass meadow cover
M2	**Pelagic ocean waters**	(Micro)plastic concentration; Water clarity;	Chlorophyll concentration; % Anoxic area; Oxygen concentration	Fish species richness; Plankton species richness	Plankton concentration or abundance	Trophic composition number (food web functionality); Ratio between fishing mortality and fishing at maximum sustainable yield	
M3	**Deep sea floors**	Light intensity; Sea floor sediment density	Oxygen concentration	Invertebrate species richness	Habitat diversity		

5.5.3 The use of data on environmental pressures

5.105 The measurement of environmental pressures is often considered as an indirect approach for measuring ecosystem condition (European Commission, 2016, p. 31). An ***environmental pressure is a human induced process that alters the condition of ecosystems*** (Maes et al., 2018). If there are little data available on state, then measures of pressures on ecosystems can be considered a useful surrogate, as long as the relationship between the two is well understood and justified (Bland et al., 2018). The ecosystem condition typology is sufficiently flexible to host variables that report pressures on ecosystems as alternatives for variables that directly measure the condition. For example, air emissions or pesticide use can be reported under chemical state; soil sealing or sea level rise can substitute physical state variables; and data on introductions of invasive alien species can be reported under compositional state. In some cases, there may be little difference between a state and a pressure indicator and, in other cases, where there is a considerable lag between evidence of a pressure and a resultant change in state, a measure of pressure may provide relevant information.

5.106 For most local pressures (e.g., poor cultivation practices, pollution, invasive species) there is an underlying variable, that reflects the ecosystem response to that pressure. This underlying variable can be considered an environmental stock (e.g., the thickness of soil layer, the concentration(s) of substances, or the abundance of species) that is gradually affected by the pressure. Typically, indicators of such stocks can meet all the selection criteria, so they can be quite appropriate for condition accounting compared to indicators of the connected flows (e.g., degradation / depletion rates, fluxes, flows, or other indicators of flow intensity).

5.107 Using indicators of environmental stocks as condition indicators comes with multiple further advantages: they can be used to formulate very clear and pertinent policy messages on ecosystem degradation (concerning a change in these environmental stocks); and the degree of policy attention highlights those environmental stocks that are perceived as the most valuable or most endangered.

5.108 Identifying environmental stocks in a condition account is particularly relevant when ecosystem extent is measured using remote sensing. Remote sensing will detect a stock loss due to a change in ecosystem type, e.g., clearing vegetation, but may not detect a stock loss due to a decline in condition (e.g., loss of understory or weed invasion). Thus, while there are distinct advantages of using indicators of environmental stocks there may be measurement challenges and hence measurement of environmental pressures may be appropriate.

5.109 An important type of environmental pressure is over harvesting, which can frequently be linked to environmental stocks (e.g., timber stocks for forests or fish stocks for marine ecosystems). In this case, the associated ecosystem types can have a specific target ecosystem service (typically a provisioning service) and traditional ecosystem management aims at the maximizing the flows of that service (de Groot et al., 2010). The intensity of these management activities has been shown to exert strong influences on the supply of a broad range of services, well beyond the original target ecosystem service (Santos-Martín et al., 2019).[53]

5.110 Where the pressure relates to expansion of agricultural activity, the effects may be captured by changes in ecosystem extent, depending on the intensity of the agricultural practices. The focus of condition measurement should then be on the change in the state of the relevant ecosystem type but measures of pressures such as livestock per hectare or rates of fertilizer

[53] Examples of the evaluation of indices include Andreasen et al. (2001); Buckland et al. (2005); Fulton et al. (2005); Rowland et al. (2020).

and pesticide use may provide important data to support policy and analysis, especially where the change in state occurs sometime after the environmental pressure is observed.

5.111 Some environmental pressure indicators (e.g., measures of GHG emissions, demographic changes) provide a broad measure of potential effects on the condition of ecosystems but will not provide direct measures of condition for individual ecosystem assets and hence are not suitable for use in ecosystem condition accounts. Rather, the focus should be on assessing the effects of these broader pressures on local ecosystems.

5.112 Indicators of protection status (e.g., the location, area, or representativeness of protected areas) are also frequently proposed as proxy measures for condition if no other information is available, e.g., Maes et al. (2016). Protection could be thought of as a rough proxy for reduced pressures, especially for reduced overexploitation (i.e., indicating lower management intensities). However, indicators describing policy interventions performed in response to management or conservation objectives are not considered appropriate as condition indicators. There is no inherent relationship between protection status and other indicators of ecosystem condition, for example, an ecosystem could be protected and nevertheless be in poor condition. In order to avoid confusion and double counting, the use of indicators describing policy response categories should be avoided. Among other issues, including such indicators would compromise the potential to use the accounts to assess the effects of policy responses, for example, the effect on condition of establishing a new protected area.

5.5.4 The role of biodiversity in ecosystem condition accounts

5.113 Following the CBD definitions, biodiversity is the variety of life within species (genetic diversity), between species, and between ecosystems (CBD article 2) and ecosystems are shaped by the interactions among species, and between species and the non-living environment (CBD article 2). As a consequence, there is overlap in how biodiversity and ecosystems are measured.

5.114 Biodiversity is integral to the maintenance of ecosystem integrity that is the reference from which the condition of ecosystem assets is assessed. Thus, in the ECT (Table 5.1) the overlap in measurement is mainly evident in the biotic ecosystem characteristics. Variables that describe species composition, ecosystem structure and ecosystem processes are also used to characterize biodiversity and are therefore considered as essential biodiversity variables.[54]

5.115 Besides overlap, there is also a difference between measuring biodiversity and ecosystem condition. Ecosystem condition accounts consider the physical and chemical quality of the ecosystem along with biotic health, and often focus on species-related metrics to account for biodiversity. Variables that describe between-ecosystem diversity are generally less appropriate and rarely used to measure the condition of a single ecosystem asset or ecosystem type. The relevant biodiversity metrics for assessing an individual ecosystem asset's condition include characteristics of composition, structure, function and landscape characteristics where these can be attributed to the condition of an individual ecosystem asset. In particular, indicators of local species diversity are likely to be relevant.

5.116 Before selecting species-based metrics to assess the condition of ecosystems, it is important to realize that there are different spatial and temporal dynamics between individual species and ecosystems. Therefore, not all species or species-based biodiversity indicators are

[54] For more information see: https://geobon.org/ebvs/what-are-ebvs/.

suitable to assess condition at all scales. For instance, to measure the long-term condition of a single ecosystem, monitoring non-mobile species that are sensitive to pollution, such as lichens, may be more appropriate and cost-effective, compared to taking observations of an occasional visiting species that only uses the ecosystem to take a rest during their seasonal migration. However, observations of the migrating species may be important in understanding the importance of that ecosystem to species conservation at a broader scale.

5.117 Consequently, some individual biodiversity metrics, such as the diversity of ecosystem types within an EAA, should not be attributed to individual ecosystem assets and should instead be considered emergent properties. As a result, these metrics will not be incorporated in aggregate measures of ecosystem condition based on the condition of individual ecosystem assets. The emergent properties can be incorporated in aggregate measures of biodiversity, for example at ecosystem type and EAA scale using aggregation approaches that appropriately consider the relevant process-related and pattern-related issues. A background paper summarising the relevant spatial aggregation issues and methodological approaches provides appropriate guidance.[55]

5.5.5 Accounting for ecosystem conversions

5.118 Ecosystem conversions occur when part or all of an ecosystem asset changes from one ecosystem type to another between the beginning and end of an accounting period. Examples of ecosystem conversions include clearing a natural forest for use by grazing animals; converting a natural grassland to cropland; draining a wetland and ploughing for agriculture; creation of a new hydropower reservoir; natural encroachment following permafrost melt; or the potential future flooding of coastal areas due to sea level rise. Chapter 4 discusses the identification and recording of ecosystem conversions, which should take place in the ecosystem extent account.

5.119 Concerning the measurement of condition, four practical measurement challenges emerge in the context of ecosystem conversions.

i. In some cases, thresholds for the condition indicators are required to identify the conversion from one ecosystem type to another. These thresholds will depend on how the ecosystem type is classified and delineated and the specific indicators applied. For example, in a conversion of a forest to a shrubland or grassland, the threshold canopy cover needs to be determined at which the ecosystem is no longer classified as a forest. Hence, rules or thresholds are required to determine changes in ecosystem type resulting in reclassification.

ii. Rules are often required to specify a time period over which the change must remain in order to be re-classified, to distinguish permanent change from temporal variability.

iii. Selection of the set of condition indicators used to describe the ecosystem types is important such that a change in the level of one or more indicators can identify a conversion to another ecosystem type. For example, the indicator of canopy cover is a poor indicator for detecting the difference between a natural forest and a plantation but a good indicator of the difference between a forest and a grassland.

iv. The spatial scale of assessment of condition indicators is important, that is the level of aggregation of spatial units for reporting within the accounting area. Metrics for

[55] The background paper on "Addressing spatial scale in deriving and aggregating biodiversity metrics for ecosystem accounting" is available at: https://seea.un.org/content/accounting-biodiversity.

condition indicators that may be used to assess conversions likely occur at different scales, from point sources to emergent landscape scales.

5.120 These measurement challenges are confronted in the first instance in the compilation of the ecosystem extent accounts described in Chapter 4. In these accounts, the change in the area of ecosystem types between the opening and closing of the accounting period is recorded in gross terms, i.e., both the additions and reductions in the area of ecosystem types are recorded. The characteristics and criteria for the delineation of ecosystems types will underpin the recording of conversions. Maintaining a time series of ecosystem extent accounts will support understanding the relative extent of different ecosystem types and support analysis of conversions from the set of ecosystem types present in a natural condition.

5.121 From an ecosystem condition measurement perspective, ecosystem condition for the converted area is measured with respect to the ecosystem type present at the end of the accounting period using the relevant characteristics and indicators. Where ecosystem conversions occur, this implies that for a converted area, the relevant set of characteristics and indicators, and the associated reference levels, will be different from those used at the beginning of the period. Significant care should therefore be taken in interpreting the change in condition over time for the converted area and, as a general approach, it is recommended that either the converted areas be excluded from the analysis of change or handled as a distinct type of area in any aggregations.

5.122 At the same time, there is often strong interest in understanding ecosystem conversions involving the change from natural to anthropogenic ecosystem types. To support analysis of these changes beyond measures of changes in extent, it may be appropriate to provide complementary measures of changes in ecosystem condition for all ecosystem types (i.e., both natural and anthropogenic ecosystems) relative to a natural reference condition. This analysis will be most relevant where changes have occurred relatively recently, for example, over the past 200 years.

5.5.6 Relationship between ecosystem condition, ecosystem capacity and ecosystem degradation

5.123 In the ecosystem accounting framework, there is the intention to record data on both the stocks of ecosystem assets and flows of ecosystem services. The general concept is that the extent and condition of ecosystem assets will have an influence on the flows of ecosystem services both in the current period and in future periods. Also, in some cases the supply and use of ecosystem services will impact ecosystem condition. The connection between these stocks and flows is reflected in the concept of ecosystem capacity. Measurement of ecosystem capacity is related to, but different from, the measurement of ecosystem condition. Section 6.5 provides a longer discussion of ecosystem capacity in the context of ecosystem accounting.

5.124 Ecosystem degradation is the decrease in the value of an ecosystem asset over an accounting period that is associated with a decline in the condition of an ecosystem asset during that accounting period (see section 10.2). Since the value of an ecosystem asset will be related to future flows of ecosystem services, there are connections among the concepts of ecosystem condition, ecosystem capacity and ecosystem degradation. However, they are not the same concept and it need not be the case that declines in condition necessarily imply ecosystem degradation. Annex 10.1 provides a discussion on the links between measures of ecosystem condition and ecosystem degradation and other changes in the value of ecosystem assets.

5.6 Applications of ecosystem condition accounts

5.125 Ecosystem condition accounts can be compiled at regional, national and international scales for a wide range of applications. Data for different components of condition accounts, such as ecosystem variables, indicators, reference levels, reference conditions and ecosystem condition indices, are used for different applications. Ensuring consistency in terms, definitions and metrics within the information system provided by the ecosystem accounts and any policies that refer to them will help ensure effective application.

5.126 Condition accounts are used to synthesize information about changes over time in the state of ecosystem assets. This information can be used to inform policy and decision-making across a range of sectors that impact or depend on ecosystems and natural resources, including land-use planning, environmental impact assessment, agricultural planning and authorization processes, and programmes for ecosystem rehabilitation or restoration. Overall measures (such as an ecosystem condition index) can be used to inform strategic planning at the national level. Where accounts are compiled with spatially explicit detail, and include information on particular characteristics of ecosystem assets, the accounts can also be used to inform landscape-level planning.

5.127 The use of variables, indicators, or ancillary information to assess the capacity of ecosystems to supply ecosystem services is an important application for the purpose of informing policy on the future availability of ecosystem service flows from ecosystem assets. As described in Chapter 10, information on future ecosystem service flows may be used for estimating a monetary value of ecosystem assets. Further, condition accounts can be used to analyse the impact that activities associated with supplying ecosystem services (e.g., timber harvesting) are having on ecosystem condition.

5.128 Several examples demonstrate the range of applications of ecosystem condition accounts in providing information. Quantification of indicators and reference levels can be used to operationalize the definition of ecosystem degradation and enhancement. Further, indicators of ecosystem condition could be combined with information on ecological thresholds (e.g., concerning points of change in ecosystem type) to assess the risk of change, or alternatively, to assess the degree of resilience within ecosystems under conditions of change. This could allow condition accounts to inform the identification of threatened ecosystems (e.g., D. A. Keith et al. (2013).

5.129 The assessment of ecosystem capacity to supply ecosystem services will depend on complex interrelationships of multiple indicators for determining threshold levels to define sustainability. Connecting the critical levels of ecosystem capacity back to the ecosystem condition variables that have the highest influence on specific ecosystem services is an important area of future research. Such research would support information in the ecosystem accounts being used to quantify the 'critical natural capital' concept described in economics (Ayres et al., 2001) or the 'planetary boundaries' concept in ecology (Rockström et al., 2009).

5.130 The development of ecosystem condition accounts has the potential to make many key policy commitments measurable, and thus more likely to be implemented, at the national and international level. The measurement may then, in turn, support the design and development of policy and associated targets. International policies where the information from ecosystem condition accounts can be applied include measures of land degradation to support the goal of land degradation neutrality (LDN) under the UNCCD,[56] the Sustainable Development

[56] See https://www.unccd.int/actions/achieving-land-degradation-neutrality

Goals,[57] and the Post-2020 Global Biodiversity Framework.[58] Further, in the UNFCCC Paris Agreement,[59] the inclusion of the concept that ecosystem integrity must be promoted while accounting for national emissions reductions demonstrates significant progress in adopting a holistic approach to environmental issues. This concept is developed further in a report describing specific mitigation actions (Dooley et al., 2018).

57 See https://www.un.org/sustainabledevelopment/sustainable-development-goals/

58 See https://www.cbd.int/conferences/post2020

59 See https://cop23.unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement

Annex 5.1: Selection criteria for ecosystem characteristics and their metrics (variables and indicators)[60]

Criterion	Short description
Conceptual criteria	
Intrinsic relevance	Characteristics and metrics should reflect the existing scientific understanding of ecosystem integrity, supported by the ecological literature.
Instrumental relevance	Characteristics and metrics should be related to the availability of ecosystem services (characteristics that exert the strongest influence on the highest priority services should be favoured)
Directional meaning	Characteristics and metrics need to have a potential for a consensual interpretation, i.e., it should be clear if a change is favourable or unfavourable with respect to ecosystem integrity
Sensitivity to human influence	Characteristics and metrics should be responsive to known socio-ecological leverage points (key pressures, management options)
Framework conformity	Characteristics and metrics should be differentiated from other components of the SEEA ecosystem accounting framework
Practical criteria	
Validity	Metrics need to represent the characteristics they address in a credible and unbiased way
Reliability	Metrics need to be accurate, reliable, and reproducible, with potential sources of error explored and documented
Availability	Metrics covering the studied spatial and temporal extents with the required resolution need to be achievable in terms of the resources and time available
Simplicity	Metrics should be as simple as possible
Compatibility	The same characteristics should be measured with the same (compatible) metrics in the different ecosystem types and/or different ecosystem accounting areas (countries)
Ensemble criteria (for the whole set of variables and indicators)	
Comprehensiveness	The final set of metrics, as a whole, should cover all of the relevant characteristics of the ecosystem, providing a complementary set of measures
Parsimony	The final set of ecosystem condition metrics should be free of redundant (correlated) variables

[60] A detailed discussion of these selection criteria is presented in Czúcz et al. (2021b).

Annex 5.2: Options for establishing reference conditions for natural and anthropogenic ecosystems

A5.1 Before selecting a reference condition against which to assess the condition of an ecosystem, it is essential to consider an appropriate assessment framework (see section 5.3.3). An assessment framework is outlined in Table 5.8 that distinguishes natural and anthropogenic ecosystem states and four possible reference conditions. In natural ecosystems, possible reference conditions are an undisturbed or minimally-disturbed condition, a historical condition, a least-disturbed condition or a contemporary condition (Jakobsson et al., 2020; McNellie et al., 2020; Stoddard et al., 2006). In anthropogenic ecosystems, possible reference conditions are a historical condition, a least-disturbed condition, a contemporary condition or a best attainable condition (Kopf et al., 2015). In semi-natural or lightly managed ecosystems, any of the four options could be used.

A5.2 The choice for an appropriate assessment framework depends on many factors and cannot be prescribed. In an accounting context, it is important that the reference condition is explicit and that the rationale for selection of the reference condition is explained. For instance, European dry heathlands, which are rich in biodiversity, can be considered as semi-natural ecosystems requiring light human management with minimal disturbance to maintain a semi-natural state and to avoid forest growth. In this case, a least disturbed or a contemporary condition may be most appropriate. In contrast, heavily polluted and drained wetlands can be considered as natural systems in poor ecological condition and assessed as such, relative to a reference condition of least-disturbed or historical condition.

A5.3 An example where the choice of reference condition may depend on the objective of the land use is a cropland that was abandoned some time ago and is reverting to a natural state. This could be assessed relative to historical condition or best-attainable condition for a land use as cropland, or relative to an undisturbed or minimally-disturbed condition for the objective of restoration. Which of these reference conditions is more appropriate will be context dependent. An intensively managed ecosystem such as an active cropland or an urban park could be assessed relative to a reference condition of best-attainable condition or contemporary condition.

Table 5.8: Assessment framework for selecting a reference condition.

Ecosystem	Possible reference conditions
Natural ecosystems: Ecosystems predominantly influenced by natural ecological processes characterised by a stable ecological state maintaining ecosystem integrity; ecosystem condition ranges within its natural variability. Examples (with reference to Table 3.2): primary and old growth forests (T1, T2), natural grasslands and savannahs (T4), natural lakes (F2) and wetlands (TF1)	**Undisturbed or minimally-disturbed condition** of an intact ecosystem. The condition of an ecosystem with maximal ecosystem integrity with no or minimal disturbance.
	Historical condition: The condition of an ecosystem at some point or period in its history that is considered to represent the stable natural state (e.g., the pre-industrial period or pre-intensive agriculture).
	Least-disturbed condition: the currently best available condition of an ecosystem.
	Contemporary condition: The condition of an ecosystem at a certain point or period in its recent history for which comparable data are available.
Anthropogenic ecosystems: Ecosystems predominantly influenced by human activities	**Historical condition**: The condition of an ecosystem at some point or period in its history

where a stable natural ecological state is unobtainable and future socio-economic interventions are required to maintain a new stable state. Examples (with reference to Table 3.2): urban green spaces and croplands (T4), artificial waterbodies (F3), anthropogenic marine systems (M4).	that is considered to represent the stable socio-ecological state (e.g., the pre-industrial period or pre-intensive agriculture)
	Least-disturbed condition: the currently best available condition of an ecosystem
	Contemporary condition: The condition of an ecosystem at a certain point or period in its recent history for which comparable data are available.
	Best-attainable condition: the expected condition of an ecosystem under best possible management practices and attaining a stable socio-ecological state.

Methods for estimating the reference condition and reference levels for ecosystem condition variables

A5.4 The following eight methods are potentially available for estimating the reference condition as a means of operationalizing the theoretical categories in Table 5.9. Methods 1-4 represent approaches that should be considered first to describe and quantify the reference condition, and in particular for establishing the values for upper and lower reference levels of ecosystem condition variables. Methods 5-7 can be considered as alternatives if methods 1-4 cannot be applied, or when policy or legislative drivers dictate methods 5 or 6 may be used. Method 7 may be particularly relevant in capturing indigenous knowledge and perspectives. Method 8 involves a combination of methods.

A5.5 **1. Reference sites**: If pristine or minimally-disturbed sites are available, they can be used to determine a reliable measure of the mean and statistical distribution of condition variables. Reference sites can be identified using expert or traditional knowledge but also by using statistics and artificial intelligence if long-term time series with data describing ecosystem disturbance are available. Monitoring reference sites is probably the most straightforward method for establishing reference conditions and for determining the reference levels of condition variables. Seasonal or annual variability but also long term or irreversible ecosystem changes due to climate change or invasive alien species can be factored in when determining reference levels for ecosystem condition variables. Reference sites can thus by used to determine a dynamic reference condition (Hiers et al., 2012) that can be periodically updated.

A5.6 **2. Modelled reference conditions** can be based on predictive empirical models or potential vegetation models. Models can be used to infer conditions in absence of human disturbance where representative reference sites are not available. Potential vegetation can be modelled globally and can incorporate scenarios of environmental change. A weakness is that models usually do not involve all the selected condition variables of the condition account, and often differ from measured variables. Models require assumptions to establish reference levels for condition variables, e.g., scientific debate on the role of megafauna and early humans on potential natural vegetation.

A5.7 **3. Statistical approaches based on ambient distributions**. Least-disturbed conditions or best-attainable conditions can be estimated by observing the range of values from current ecosystem monitoring and by selecting a reference condition, for instance based on the 5th percentile values as criterion or by assuming that the reference condition is equal to a state with the highest species richness. Statistical approaches are data-driven and therefore pragmatic, familiar for accountants, and applicable if no reference sites are available. Methods can be applied consistently across variables, e.g., normalizing with the maximum values of available data. Possible drawbacks are the arbitrary nature of the reference condition, spatial inconsistencies caused by using current datasets, a strongly shifting baseline, or a false sense of consistency. Solutions need to be proposed to scale condition variables at levels outside the range of the available data. Variables moving out of their established range (e.g., improving beyond the previous upper reference level) can cause serious complications.

A5.8 **4. Historical observations and paleo-environmental data.** This method uses historical observations or paleontological data to describe a historical reference condition (typically before 1970 when routine environmental monitoring programmes started). Historical observations refer to a description of a reference condition based on species collections in natural history museums, historical manuscripts and books that describe fauna and flora, photo archives, paintings, or other material that can be used to make inferences about the presence of species or the prevalence of certain conditions during a certain period in time. Paleo-environmental data can be used to reconstruct the physical-chemical environment, climate, vegetation and fauna of certain period in time using material that is buried in the soil. These data are often collected during archaeological studies. Examples of relevant data collections to define a historical ecosystem condition include seedbanks to reconstruct flora or remains of fish catches nearby medieval settlements to reconstruct the fish fauna or determine the presence of specific species. This method can deliver a common baseline for climate and biodiversity science, which is relevant to support more integrated climate-biodiversity policies. This method can also show the magnitude of loss of biodiversity. A weakness is that not all ecosystem condition variables can be easily inferred from historical data.

A5.9 **5. Contemporary data.** This method uses contemporary data to describe a contemporary reference condition (typically after 1970 when routine environmental monitoring programmes started). For instance, the Kyoto protocol used the global atmospheric CO_2 emissions recorded in 1990 as a reference against which the changes in future greenhouse gas emissions were assessed. The Living Planet Index uses species data collected in 1970 as a reference to assess changes. Similar to statistical approaches that use ambient data distributions, this is a straightforward approach to set a reference condition provided data are available. However, there are several disadvantages. The choice of year may be considered arbitrary. The reliance on contemporary data in evaluating changes can result in a shifting baseline. Appropriate dates differ for different indicators and ecosystem types. If different baseline dates are used in different regions this creates inconsistencies. Difficulties arise for scaling condition variables at levels which are higher than their reference level, e.g., when variables move out of their established range. The method is subject policy influence and contemporary baselines may diverge greatly from pre-industrial era baselines.

A5.10 **6. Prescribed levels** of a set of ecosystem condition variables can be used to construct a bottom-up reference condition. Examples of these reference levels include zero values for emissions or pollutants, a specific number of species, established sustainability or threshold levels such as critical loads for eutrophication and acidification, and target levels in terms of legislated quality measures (air and water quality). Prescribed levels of variables can have clear and straightforward management applications and provides a basis for direct policy response. This method can reflect preferences for a particular use of an ecosystem accounting for social, economic and environmental considerations. They can also describe a level quantifying an undesirable state required to define the zero end of the normalized scale, for example, where the ecosystem is no longer present or functioning. Prescribed levels are, however, not available for all variables, may be subject to policy influence and changing over time, and may not be consistently developed for all ecosystem types, variables or countries.

A5.11 **7. Expert opinion** usually consists of a narrative statement of expected reference condition. Although an expert´s opinion may be expressed semi-quantitatively, qualitative articulation is probably most common (European Commission, 2003). Several weaknesses are inherently associated with this approach. Therefore, caution should be exercised when using this approach as the sole means of establishing reference condition.

A5.12 **8. Combination of any of the above methods**. Many of the above approaches may be used either singly or in concert for establishing and/or cross-validating reference condition. In practice, it may not be possible to use a single method to describe or quantify reference levels of ecosystem condition variables under a reference condition. For instance, the reference values of variables that describe a historical condition (for instance a pre-industrial state of an ecosystem) can be determined by combining modelling potential vegetation (method 2) based on paleo-climatic data (obtained through method 4). Statistical models and tools exist to combine methods (e.g., Bayesian networks can combine statistical distributions (method 3) and expert opinion (method 7)). Recent advancements in artificial intelligence will further improve the above mentioned methods to infer and describe a reference condition.

Table 5.9: Summary of methods for estimating possible reference condition for natural and managed ecosystems

	Natural ecosystems				
		Anthropogenic ecosystems			
Possible reference condition	Undisturbed or minimally-disturbed condition	Historical condition	Least-disturbed condition	Contemporary condition	Best-attainable condition
Methods for estimating the reference condition					
1. Reference sites	x	x	x	x	
2. Modelled reference conditions	x	x	x		x
3.Statistical approaches based on ambient distributions			x		x
4.Historical observations and paleo-environmental data		x			
5. Contemporary data				x	
6. Prescribed levels					x
7. Expert opinion	x		x		x

SECTION C: Accounting for ecosystem services

Section overview

The broad ambition of the SEEA is to describe in a comprehensive manner the relationship between the environment and the economy. In many respects, flows of ecosystem services which describe the contributions that ecosystems make to benefits used in economic and other human activity are a central part of describing this relationship. SEEA EA, Section C, encompassing chapters 6 and 7, describes the approach to accounting for ecosystem services within the ecosystem accounting framework described in chapter 2.

The focus in chapter 6 is on the definition of ecosystem services and associated concepts for accounting purposes. The concept of ecosystem services is relatively new with a rapid increase in research and accompanying literature and studies occurring in the past 20 years. It has therefore been important to clearly articulate the approach in the SEEA. An important part of this articulation is establishing the connection to the flow of produced goods and services that are recorded in the SNA. Thus, ecosystem services are defined such that, as appropriate, they can be readily recorded as inputs to production processes recorded in the SNA. At the same time, the measurement boundary for ecosystem services extends to include the contribution of ecosystems to other, non-SNA, benefits that people receive from the environment.

In accounting for ecosystem services, the emphasis is placed on recording data on the use of ecosystems by economic units and people both directly and indirectly. Often there are competing interests wherein some people's use, for example to supply wood biomass, competes with other uses such as global climate regulation. In other cases, the uses may be complementary. The intent in accounting terms is to record the flows that occur and hence support an understanding of the degree to which different uses may be competing or complementary and the extent to which some uses may have more effect on ecosystem condition and the continued supply of ecosystem services.

There is a range of measurement boundary and treatment issues such as those concerning links to biodiversity, the treatment of non-use values and the treatment of imports and exports of ecosystem services. All of these matters are considered in chapter 6. Chapter 7 focuses on the appropriate recording of ecosystem services in physical terms using accounting principles. These chapters demonstrate the importance of the SEEA EA in establishing an agreed set of concepts, definitions and measurement classes for ecosystem services to support the effective exchange of experience and development of standard reports and outputs.

In many contexts, data about ecosystem service flows in physical terms will provide the core information in understanding the connection between people and ecosystems, for example concerning the location of ecosystem supply, the types of users and beneficiaries and the magnitude of the flows. This is particularly relevant for measurement in monetary terms since the majority of ecosystem services are not traded on markets and values for ecosystem service flows must be estimated using various non-market valuation approaches as described in chapter 9.

6 Ecosystem services concepts for accounting

6.1 The purpose in accounting for ecosystem services

6.1 In the ecosystem accounting framework, ecosystem services serve as the connecting concept between ecosystem assets and the production and consumption activity of businesses, households and governments. The measurement of ecosystem services is thus central to describing an integrated set of ecosystem accounts.

6.2 Since the release of *Ecosystems and Human Well-being* (Millennium Ecosystem Assessment, 2005), there has been a significant increase in the number of studies focused on ecosystem services. These studies, involving researchers from a range of disciplines from all over the world, have considered many aspects of definition and approaches to measurement, including at scales from local ecosystems and communities to global assessments. The potential of applying an ecosystem services approach to foster an understanding of the relationship between humans and the environment has been further strengthened through work in various initiatives including The Economics of Ecosystems and Biodiversity initiative (TEEB, 2010), the Mapping and Assessment of Ecosystems and their Services (MAES) initiative (Maes et al., 2013); the Natural Capital Project at Stanford University; the Integrated system for Natural Capital Accounting (INCA) project (Vallecillo et al., 2019); and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Díaz et al., 2015); among many others. The approach to accounting for ecosystem services presented here builds on all of this research and practice.

6.3 The measurement of ecosystem services is of particular interest in explaining the variety of contributions that ecosystems make to people and the economy. These contributions extend well beyond those of marketed goods, such as timber and fish, and include services such as air filtration, water purification, global climate regulation and recreation-related services. Commonly, these types of services are supplied to communities outside market institutions. The focus of accounting for ecosystem services is to provide a clear description of the range of these services, the spatial heterogeneity of their delivery, and the local to global beneficiaries of these services, in order that this information can be readily compared between and connected to the different ecosystems that supply the services.

6.4 An important part of the rationale for accounting for ecosystem services is that while much economic production (for example, in agriculture, forestry and fisheries) uses inputs directly from ecosystems, those inputs (and any associated degradation) are not explicitly recorded in the national accounting framework. In ecosystem accounting, ecosystem services are clearly differentiated from the goods and services that are produced, i.e., the ecosystem services are recorded as the contributions of ecosystem assets to the production of those goods and services. In effect, the approach here extends supply chains and treats ecosystem assets as suppliers or producing units.

6.5 The explicit recording of the contribution of ecosystems to both current marketed production and wider benefits accruing to individuals and society, encourages a wider understanding of the role of ecosystems and the effects that may arise when the extent and condition of ecosystems change (e.g., due to changes in land-use, spatial planning, and protected status). This focus can particularly support understanding those ecosystem services that may be at risk of being lost or becoming scarce.

6.6 Accounting for ecosystem services does not provide a complete assessment of the entire relationship between ecosystems and people. While the conceptual scope of ecosystem services is broad, there are a range of other benefits that are not captured, for example concerning relational and intrinsic values. Nonetheless, a focus on ecosystem services does provide an important piece of information in describing our use of, and dependence on, ecosystems. Further, together with information on the extent and condition of ecosystem assets, data about expenditure on environmental protection and resource management, and data on economic activity, a rich picture of the relationship can be portrayed. In this respect, there is an important link to the data of the SEEA Central Framework and the SNA in understanding relevant environmental pressures and policy responses. How these factors impact on ecosystem assets and hence on the flows of ecosystem services is an important area for informing relevant aspects of policy-making.

6.7 This chapter provides descriptions and definitions of the various concepts and principles that are applied in accounting for the supply and use of ecosystem services. Using these concepts and principles, the chapter outlines a reference list of selected ecosystem services and associated descriptions to support account compilation and comparison of methods and findings. The chapter also provides additional explanation on the treatment of specific services and associated environmental flows thus establishing the measurement scope that is appropriate for ecosystem accounting.

6.2 Concepts and principles in accounting for ecosystem services

6.2.1 Ecosystem services

6.8 The key concepts of the ecosystem accounting framework related to ecosystem services concern (i) the supply of ecosystem services to users; and (ii) the contribution of ecosystem services to benefits (i.e., the goods and services ultimately used and enjoyed by people and society). The following paragraphs place these concepts in context for ecosystem accounting purposes.

6.9 Following the general framework of ecosystem accounting, each ecosystem asset supplies a set or bundle of ecosystem services. Following the framing described in Chapter 2, ***ecosystem services are the contributions of ecosystems to the benefits that are used in economic and other human activity***. In this definition, use incorporates direct physical consumption, passive enjoyment and indirect receipt of services. Further, ecosystem services encompass all forms of interaction between ecosystems and people including both in situ and remote interactions.

6.10 In ecosystem accounting, ecosystem services are recorded as flows between ecosystem assets and economic units; where economic units encompass the various institutional types included in the national accounts, such as businesses, governments and households. Flows of ecosystem services are sometimes reflected in direct physical flows, such as when fish are removed from a marine ecosystem, but may also be reflected in the indirect receipt of ecosystem services, such as flood control services.

6.11 Following the cascade model describing flows of ecosystem services,[61] the supply of an ecosystem service will be associated with an ecosystem structure or process or a combination of ecosystem structures and processes that reflect the biological, chemical and physical interactions among ecosystem components (Potschin & Haines-Young, 2017). Their characteristics can be aggregated into different groups of functional outcomes (Schneiders & Müller, 2017). These processes and characteristics are observable and measurable but are not themselves flows of ecosystem services as defined in ecosystem accounting since this requires

[61] This framing reflects the general framing of the well-recognised cascade model (Haines-Young & Potschin, 2012; Potschin & Haines-Young, 2016) and the framing provided by Boyd & Banzhaf (2007). Central to these framings is that ecosystem services are “contributions to benefits” rather than being “equivalent to benefits” which was the framing applied in the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005). The language of contributions is also present in the approach of IPBES (Díaz et al., 2015) which adopts the term “nature’s contributions to people”. The focus on contributions directly suits the accounting approach of the SEEA EA and the application of supply-use principles.

a connection to be made to users. This alignment between supply and use is a foundational accounting concept (see SEEA Central Framework, Section 3.2) and applies in both physical and monetary terms. The recording of ecosystem services will pertain to total flows over an accounting period (e.g., one year) and thus an entry will reflect a total flow per unit of time.

6.12 In much of the ecosystem services literature, the term supply is used to refer to an ecosystem's potential or capacity to supply services irrespective of use, while the term use is applied to refer to the actual flow to people. In ecosystem accounting, following standard accounting treatments, the measures of supply and use are equivalent and will be equal to the actual flow between the ecosystem asset and people. Nonetheless, the concept of ecosystem capacity is highly relevant. Section 6.5 provides a discussion on this concept in the context of ecosystem accounting.

6.13 In many cases, ecosystem services will contribute to benefits in combination with other inputs such as labour and produced capital. These "joint production" contexts are an important feature of the relationship between ecosystem assets and economic and other human activity and they highlight the need to differentiate between ecosystem services and benefits. The types of benefits are discussed further in section 6.2.2.

6.14 The relationship between the supply of ecosystem services and the use of ecosystem services will not always be from one ecosystem asset to one economic unit or user. In some cases, ecosystem services will be supplied through a combination of ecosystem assets, for example flood control services involving a range of ecosystem types within a catchment. In other cases, one ecosystem service will be used by different economic units. For example, air filtration services will contribute to benefits used by both households and businesses. The types of users are linked to different types of benefits and are discussed in section 6.2.2.

6.15 In some cases, the ecosystem services will be an indirect contribution to benefits, for example, where the nursery population services supplied by seagrass meadows are an input to the supply of fish biomass provisioning services, which in turn contribute to the benefit of marketed fish. In this case, the nursery population service is treated as intermediate while the biomass provisioning service is final. Final and intermediate ecosystem services are discussed further in section 6.2.3.

6.2.2 Benefits

6.16 ***Benefits are the goods and services that are ultimately used and enjoyed by people and society.*** The use of the term benefit in ecosystem accounting derives from, but is applied more broadly than, the SNA definition of an economic benefit. In the SNA, "*an economic benefit is defined as denoting a gain or positive utility arising from an action*" (2008 SNA, 3.19) where an action or activity concerns production, consumption or accumulation and utility concerns the satisfaction of a human need or an improvement in well-being.[62] As applied in ecosystem accounting, a benefit will reflect a gain or positive contribution to well-being arising from the use of ecosystem services.

6.17 Benefits are treated as either SNA benefits or non-SNA benefits. ***SNA benefits are goods and services that are included in the production boundary of the SNA.*** Examples of SNA benefits include all food, water, energy, clothing, shelter and recreation services available for purchase. As contributions to SNA benefits, ecosystem services are readily seen as inputs into an existing production process and consequently SNA benefits can be seen as resulting from

[62] As in the SNA, the term utility is used here in the sense of providing a conceptual reference point rather than a measurement objective.

a joint production process involving ecosystems and various other inputs including produced assets and labour. It may be useful to distinguish between inputs involved in the supply of ecosystem services (e.g., the use of fertilizers in the growing of crops) and inputs involved in accessing or using ecosystem services (e.g., use of vehicles to drive to parks for recreation). In both contexts, the aim in ecosystem accounting is to isolate and record the ecosystem's contribution to the benefits received.

6.18 ***Non-SNA benefits are goods and services that are not included in the production boundary of the SNA.*** Examples of non-SNA benefits include clean air and flood protection provided by ecosystems. In line with the definition of benefits, the scope of non-SNA benefits for ecosystem accounting purposes is limited to the contributions to people and society. It therefore excludes contributions of ecosystems to their own longer-term condition and potential to supply ecosystem services in the future. While there may be benefits associated with maintenance of ecosystem condition, these are either reflected in the ecosystem accounts via the ecosystem condition account or in terms of changed flows of ecosystem services which are recorded at the time they occur.

6.19 The measurement scope of ecosystem services is set such that flows of ecosystem services do not overlap with the flows of goods and services recorded in the SNA (i.e., SNA benefits). The measurement scope of goods and services recorded in the SNA is defined by the SNA production boundary. In ecosystem accounting, all ecosystem services are outside the SNA production boundary.

6.20 It is also relevant to consider the private and public nature of the ecosystem services and the link to benefits. Three situations can be described.

i. There are ecosystem services that contribute to benefits that are used by one user and it is feasible to exclude other users from their use (e.g., the supply of fodder in rearing livestock on private land holdings). Such ecosystem services satisfy the economic definition of pure private goods being rival and excludable.

ii. There are ecosystem services that contribute to benefits that are used by one user but it is not feasible to exclude other users from it use (e.g., recreation-related services supplied by a public park). Such ecosystem services satisfy the economic definition of common pool resources being rival and non-excludable.

iii. There are ecosystem services that contribute to benefits that can be used simultaneously by multiple economic units and it is not feasible to exclude others from using the service (e.g., global climate regulation services). Such ecosystem services satisfy the economic definition of pure public goods being non-rival and non-excludable.

6.21 An application of these distinctions is that those ecosystem services that contribute to public goods can be treated analogously to those services treated in the SNA as collective consumption. These distinctions are relevant in the allocation of ecosystem services to users (as discussed further in Chapter 7) and in the integration of ecosystem services and ecosystem assets in the extended sequence of sector accounts described in Chapter 11.

6.22 As noted, there is a link between the definition of benefits and well-being. In a wider economic framing, well-being is commonly described in terms of welfare and utility[63] which in turn may be linked to the consumption of goods and services[64] and the receipt of benefits. In this

[63] Well-being may also be expressed in terms of capabilities (Sen, 1999).

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

context, the assessment of changes in welfare and well-being will consider both positive and negative effects on utility.

6.23 From an accounting perspective, a distinction can be made between outputs and outcomes (see OECD (2008)). For example, health outputs concern the production of services supplied by doctors and hospitals, while health outcomes will reflect a particular state or condition to which people attach utility. In this framing, outputs contribute to outcomes. There may be considerable analytical interest in estimating the value of health and other individual and social outcomes but this is not the focus of measurement in ecosystem accounting.

6.2.3 Final and intermediate services

6.24 The primary focus of ecosystem accounting is on the measurement of final ecosystem services. ***Final ecosystem services are those ecosystem services in which the user of the service is an economic unit.*** Economic units include businesses, governments and households. Thus, every final ecosystem service represents a flow between an ecosystem asset and an economic unit.

6.25 A focus on accounting for final ecosystem services is appropriate where the focus of measurement is on the direct connection between people and ecosystems. However, there is a range of connections among ecosystem assets involving a range of ecosystem structures and processes that will be relevant in determining the supply of final ecosystem services. For example, populations of wild fish may be caught at sea while the associated nurseries are located in seagrass meadows closer to shore. Thus, while the overall contribution of ecosystems will be embodied in the catch of wild fish (a final ecosystem service), this recording will not reveal the indirect contribution of the seagrass meadows.

6.26 Conceptually, the ecosystem accounting framework allows the indirect contributions of ecosystem assets to be recorded as intermediate services. As for final ecosystem services, intermediate services represent contributions to benefits. Thus, ***intermediate services are those ecosystem services in which the user of the ecosystem services is an ecosystem asset and where there is a connection to the supply of final ecosystem services.***

6.27 Since intermediate services are defined with respect to a sequence of inputs and outputs within the environment, there is the potential for them to be recorded both within and between ecosystem assets. For example, the nursery services provided by seagrass meadows may contribute to fish caught in either the same location or elsewhere. This treatment allows the recording of intermediate services, and hence the various indirect contributions of ecosystems, to be undertaken irrespective of the size of the ecosystem assets. Chapter 7 elaborates further on the approach to recording intermediate services in ecosystem accounting, particularly as it concerns recording ecosystem services related to the production of biomass, such as crops.

6.28 For ecosystem accounting purposes, the measurement of intermediate services should generally focus on cases where there are observable connections between ecosystem assets that are of high analytical or policy interest, for example concerning the role of wild pollinators in supporting the production of crop biomass, or connections among trophic layers for fish species.

6.29 Potentially, quite complex interlinkages between different ecosystems can be recorded within a supply and use accounting structure. However, the focus of ecosystem accounting should remain on recording final ecosystem services and entries for intermediate services should concern only those flows that can be clearly connected to a final ecosystem service and that are of particular relevance for ecosystem management – as in the examples above. It is not the ambition in ecosystem accounting to provide a full documentation of all ecological processes or connections.

6.30 Recording intermediate services as exchanges among ecosystem assets is not equivalent to recording the wide array of biophysical flows within and between ecosystems that reflect ongoing ecological processes and associated characteristics. Such flows were referred to in the SEEA 2012 EEA as intra- and inter- ecosystem flows. Certainly, these processes and associated characteristics are fundamental to the supply of ecosystem services but a complete mapping of intra- and inter- ecosystem flows is beyond the scope of ecosystem accounting. Nonetheless, there will be interest in understanding the extent to which the various ecological processes are well-functioning, for example in understanding the ability of an ecosystem to provide ecosystem services into the future. In ecosystem accounting, the maintenance of well-functioning ecosystems is considered in the measurement of ecosystem condition and ecosystem capacity.

6.2.4 Users and beneficiaries

6.31 In accounting, the supply and use of ecosystem services in the production of benefits can be considered, in many contexts, as the first step in a longer economic “supply” chain. For example, a water supply company’s use of water purification services will be an initial step in the abstraction and distribution of water to a wide range of economic units, including businesses, governments and households. For clarity of expression, all of these economic units may be referred to as beneficiaries of ecosystem services but the economic unit that has the direct connection to the ecosystem, i.e., the unit that is the counterparty in the interaction with the ecosystem, is labelled the user of the ecosystem service. In this example, the user of water purification services is the water supply company while the other economic units would be beneficiaries. Users should be considered a sub-set of beneficiaries.

6.32 In recording flows of ecosystem services to various users and beneficiaries, it will be relevant to consider the location of use relative to the location of the supplying ecosystem. This will extend to consideration of imports and exports of ecosystem services and the associated benefits. The mapping of ecosystem service flows to users and beneficiaries, and the recording of exports and imports of ecosystems services is discussed further in Chapter 7.

6.2.5 Abiotic flows

6.33 The discussion and literature on ecosystem services has tended to focus on those flows that are primarily associated with an ecosystem’s biotic components and processes, i.e., flows associated with living components such as plants and animals. However, since the definition of an ecosystem involves the interaction of biotic and abiotic components, a neat separation that treats ecosystem services as purely or predominantly “biotic,” is not appropriate.

6.34 Further, there is a range of benefits that people obtain from the environment that reflect contributions which appear to fall outside the scope of ecosystem services. Examples include extraction of fossil fuels and mineral ores, abstraction of water, energy obtained from wind and solar sources and the role of the soils and bedrock in supporting buildings and transport infrastructure.

6.35 To support discussion of these various flows and the appropriate and comparable recording with respect to ecosystem services, the SEEA EA adopts a framing of contributions from the environment that distinguishes (i) ecosystem services; (ii) abiotic flows; and (iii) spatial functions, as shown in Table 6.1. In this framing, ***abiotic flows are contributions to benefits***

from the environment that are not underpinned by, or reliant on, ecological characteristics and processes.

6.36 Key features of this framing are that:

- Ecosystem services are distinct from abiotic flows while both reflect contributions from the environment.
- Ecosystem services are underpinned by various ecological characteristics and processes which will involve both biotic and abiotic components to varying degrees. Thus, ecosystem services encompass services which are both predominantly "biotic" (e.g., air filtration services by forests) and predominantly "abiotic" (e.g., coastal protection services by sand dunes).
- Abiotic flows arise through the abstraction and extraction of resources where a distinction is made between those flows related to geophysical sources, i.e., sources related to climate and the atmosphere; and those related to geological resources. Depending on the location of the resources and the point of abstraction or extraction, geological resources may be attributed as flows from ecosystem assets (e.g., sand and gravel) or from deep geological resources.
- Spatial functions are not treated as either ecosystem services or abiotic flows. Two main types are identified (i) the use of the environment for transportation and movement on land, water or through the air or as the base for buildings and structures; and (ii) the use of the environment as a location in which pollutants and waste are deposited, i.e., use of the environment as a sink (beyond the remediation of such residuals by ecosystems which is treated as an ecosystem service). [65]

6.37 Compilers are encouraged to record abiotic flows from geophysical sources and from geological resources extracted from ecosystem assets together with ecosystem services since analysis of environmental trends for spatial areas may be enhanced greatly from joint consideration of these flows. This is particularly the case for flows of water. Indeed, the treatment of water abstraction and supply is very important and discussed explicitly in section 6.4. There is no expectation that compilers of ecosystem accounts will record abiotic flows from deep geological resources or flows relating to spatial functions. Accounting for abiotic flows should be undertaken consistent with the advice of the SEEA Central Framework, for example concerning flows of energy, water and mineral and energy resources.

Table 6.1: Contributions from the environment

Ecosystem services* Provisioning services Regulating and maintenance services Cultural services	
Abiotic flows	Geophysical sources Flows related to geophysical processes including abstraction of water (including groundwater), and capture of wind, solar, tidal, geothermal and similar sources of energy.
	Geological resources Flows related to geological resources including extraction of fossil fuel, mineral ores, sand & gravel.
Spatial functions	Flows related to the use of the environment as the location for transportation and movement, and for buildings and structures.

[65] Potentially, this could be extended to include recording the use of the atmosphere as a sink for greenhouse gas emissions but this treatment is not developed in the SEEA EA.

	Flows related to the use of the environment as a sink for pollutants and waste (excluding the remediation of pollutants and wastes recorded as ecosystem services).

* Following the treatment described in section 6.3.4, non-use values are not treated as ecosystem services but data concerning them may be recorded as "Ecosystem and species appreciation" to recognise these connections to the environment.

6.38 Concerning flows of pollutants and waste, it is noted that there will be related entries in the ecosystem service flow accounts concerning the mediation of these residuals, and the accounts of the SEEA Central Framework provide the opportunity to record aggregate flows of these pressures. The effect of these pressures on ecosystem condition should be recorded in the ecosystem condition account.

6.39 Flows related to the use of the environment as the location for transportation and movement, and for buildings and structures are not recorded explicitly in the SEEA Central Framework or SEEA EA. Relevant information may be recorded in the SEEA Central Framework land use accounts.

6.40 The monetary value of abiotic flows and spatial functions will generally be captured in current SNA based values, for example in the value of resources extracted or in market values that capture the use of land to support buildings and structures, with the main exception concerning the use of the environment as a sink for pollutants and waste.

6.2.6 Identifying flows of ecosystem services

6.41 To support consistent application of the boundary between ecosystem services and benefits, a tool referred to as a "logic chain" is applied. The intent is to provide a standard framing for recording information relevant to the description and measurement of individual ecosystem services. A logic chain reflects a sequence in which an ecosystem asset supplies an ecosystem service to an economic unit who uses that ecosystem service as an input to a production or consumption activity which leads to an SNA or non-SNA benefit. Logic chains can be shown graphically but may also be shown in a table as shown in Table 6.2.

Table 6.2: Generic logic chain (with example of air filtration services)

Ecosystem Service	**Common ecosystem type/s**	**Factors determining supply**		**Factors determining use**	**Potential physical metric(s) for the ecosystem service**	**Benefits**	**Main users and beneficiaries**
		Ecological	**Societal**				
Air filtration services	Forest and woodland	Type and condition of vegetation, especially Functional State (e.g., Leaf Area Index) and Chemical State (e.g., ambient pollutant concentration)	Ecosystem management; location type and volume of released air pollutants	Behavioural responses; and location and number of people and buildings affected by pollution	Tonnes of pollutants absorbed by type of pollutant (e.g., PM10; PM2.5)	Reduced concentrations of air pollutants providing improved health outcomes and reduced damage to buildings (non-SNA benefit)	Households; businesses (through reduced damage to buildings)

6.42 As shown in Table 6.2, each logic chain for a given ecosystem service has a number of components: (i) the ecosystem service; (ii) the common ecosystem types; (iii) factors determining supply; (iv) factors determining use; (v) potential physical metrics; (vi) the associated benefit/s and (vii) the main users and beneficiaries. The following points are highlighted in respect of each component:

- *Ecosystem services*: A logic chain should focus on a single ecosystem service recognising that it may contribute to a number of benefits.
- *Common ecosystem types:* All ecosystem services are treated as being supplied by ecosystem assets, either individually (e.g., forest providing air filtration services to a neighbouring town) or in combination (e.g., ecosystems within a catchment providing water flow regulation services).
- *Factors determining supply*: Both ecological and societal factors should be considered in describing factors determining supply. From an ecological perspective, particular ecosystem characteristics may be relevant to the supply of ecosystem services, for example the presence of particular species, or soil type; or aspects of ecosystem condition, such as pollutant concentrations and soil organic carbon levels. Human factors can determine the supply of regulating services, for example, the service of air filtration requires that there is some release of air pollutants. Further, where there are cases of joint production of benefits, for example in the growing of crops, it will be relevant to recognise the human inputs such as labour, produced assets (e.g., tractors) and intermediate consumption of goods and services (e.g., fuel, fertilizer).
- *Factors determining use*: In addition to describing the factors involved in supply, it will be relevant to describe how people and economic units engage with the ecosystem in order to use the ecosystem service. In the case of air filtration, the relevant factors concerning use will be the number of people in proximity to the relevant forest or other type of ecosystem. Without a description and quantification of the use, no flow of an ecosystem service should be recorded. Where the logic chain concerns an intermediate service, the connection to people and economic units will be indirect and should focus on the way in which the receiving ecosystem asset uses the ecosystem service.
- *Potential physical metrics*: A physical metric is needed that gives a clear focus for measurement recognising that this metric may be a proxy for the ecosystem service and will vary depending on the data availability. For example, for air filtration a suitable metric will be the tonnes of pollutant absorbed by type of pollutant (e.g., PM2.5, PM10).
- *Benefits*: While the focus of ecosystem accounting is on identifying the contribution of ecosystems reflected in ecosystem services, commonly it will be through the observation of the benefits that the identification of the role of ecosystems can be described. For air filtration, the benefit of reduced concentrations of air pollutants will be received by households with respect to improved health and by building owners in terms of reduced damage to property.
- *Main users and beneficiaries:* Different economic units will use the ecosystem services, in some cases the same service may be used by different types of economic units. For example, air filtration services will be used by households and businesses.

6.43 Following the design of the generic logic chain in Table 6.2, indicative logic chains for a range of ecosystem services have been included in Annex 6.1 to support measurement and implementation. On online supplement is being developed that will outline the logic chains for all ecosystem services included in the reference list.

6.3 The reference list of selected ecosystem services

6.3.1 Principles of the reference list of selected ecosystem services

6.44 Within the conceptual scope of the ecosystem services definition there are a wide range of ecosystem services. Notwithstanding strong advances in the development of classifications of ecosystem services, in particular the Common International Classification of Ecosystem Services (CICES)[66] and the National Ecosystem Service Classification System (NESCS Plus),[67] an internationally agreed classification of ecosystem services has not been finalized. In its absence, a reference list of selected ecosystem services has been developed for the SEEA EA by combining the findings from the CICES, NESCS and other work (e.g., MA, TEEB and IPBES-NCP) on the typology and classification of ecosystem services, and the outcomes of the consultation on the revised SEEA EA. The primary criterion for inclusion in the reference list of selected ecosystem services is that the service is considered to constitute a relevant and important ecosystem service in many countries and contexts.

6.45 The reference list of selected ecosystem services provides labels and descriptions for a set of key ecosystem services relevant for ecosystem accounting. It is intended to provide clarity on the measurement scope and focus with respect to ecosystem services and should therefore support consistency of measurement. In this way, the reference list will support discussion among ecosystem accounts compilers, the comparison of measurement and valuation techniques and the comparison of accounting results.

6.46 The reference list is a pragmatic grouping of ecosystem services to support accounting and is not a full ecosystem service classification system. It is intended that a complete and internationally agreed classification of ecosystem services will be developed. To support this development and to allow those using existing classification systems to link to the reference list, correspondences to CICES and NESCS and other ecosystem services classifications and typologies are available as an online supplement to SEEA EA.

6.47 Since it contains selected ecosystem services, the reference list is not exhaustive. However, it does include categories for "other ecosystem services" to allow for services not included in the list to be recorded in the ecosystem accounts, subject to them satisfying the definition of ecosystem services used in the SEEA EA and associated treatments. Where additional ecosystem services are included in a set of ecosystem accounts, it is important that the description, labelling and measurement of those ecosystem services ensures that they do not overlap with other services included in the reference list. This will avoid double counting of ecosystem services and will facilitate comparisons between accounts.

6.48 Each ecosystem service in the reference list is described such that there is no double-counting of the ecosystem contributions of individual ecosystem services in the reference list. The focus in applying this principle will vary by type of ecosystem service. For provisioning services, the mutual exclusivity will be connected with using a classification of biomass outputs such as of agricultural products. For regulating services, the focus is on distinguishing the roles of different ecological processes. For cultural services, the focus is on describing the types of interactions that individuals have with ecosystems, for example whether they take place within ecosystems or outside.

6.49 Further, the reference list includes ecosystem services that can be either final ecosystem services (i.e., used by economic units) or intermediate services (i.e., used by ecosystem assets) Further, particularly for regulating and maintenance services, a single ecosystem service may be final or intermediate depending on the context. The distinction between final and

[66] https://cices.eu/resources/

[67] https://www.epa.gov/eco-research/national-ecosystem-services-classification-system-nescs-plus

intermediate is a reflection of the user of the service not the service itself. In concept, since each ecosystem service flow is recorded separately, a distinct treatment as either final or intermediate can be determined depending on the use context. Particularly in accounting for biomass provisioning services, care will be needed to ensure that the appropriate combination of inputs and outputs of ecosystem services are recorded such that the net contribution of the ecosystem assets is identified. Chapter 7 provides further discussion on the appropriate recording of ecosystem services following a supply and use table approach.

6.50 Following the requirements of ecosystem accounting, the reference list does not incorporate a distinction based on the type of supplying ecosystem asset or a distinction based on the nature of the use of the ecosystem service (e.g., whether for use by households or business, for nutrition or energy, etc.). The information on the supplying ecosystem assets and the using economic units will be evident from the place in the supply and use table where the ecosystem service flow is recorded. The supply and use tables will apply existing classifications of ecosystem types (e.g., IUCN GET or equivalent national classification) and economic units (e.g., International Standard Industrial Classification or equivalent national classification) to organize information on each ecosystem service flow.

6.3.2 The reference list of selected ecosystem services

6.51 The reference list of selected ecosystem services and associated descriptions is shown in Table 6.3. The list is structured at the highest level into three broad categories: provisioning services; regulating and maintenance services and cultural services.

- ***Provisioning services are those ecosystem services representing the contributions to benefits that are extracted or harvested from ecosystems.***
- ***Regulating and maintenance services are those ecosystem services resulting from the ability of ecosystems to regulate biological processes and to influence climate, hydrological and biochemical cycles, and thereby maintain environmental conditions beneficial to individuals and society.***
- ***Cultural services[68] are the experiential and intangible services related to the perceived or actual qualities of ecosystems whose existence and functioning contributes to a range of cultural benefits.***

6.52 Within each of these broad groups a number of ecosystem service types are included with some sub-types also listed. The regulating and maintenance services are grouped roughly according to the topics of climate, air, soil, water and habitat and species related services.

6.53 To ensure that the coverage of the ecosystem accounts is as comprehensive as possible, compilers are encouraged to include as many types of ecosystem services as possible. A progressive expansion in the range of ecosystem services included in the accounts over time may be appropriate, considering data and resource availability and the relative significance of the ecosystem services.

6.54 Notes are provided following Table 6.3 to support understanding of the table and its application. Additional detail on some of these notes is provided in section 6.4 concerning the treatment of selected ecosystem services.

[68] The label “cultural services” is a pragmatic choice and reflects its longstanding use in the ecosystem services measurement community. It is not implied that culture itself is a service, rather it is a summary label intended to capture the variety of ways in which people connect to, and identify with, nature and the variety of motivations for these connections.

Table 6.3: Reference list of selected ecosystem services

ECOSYSTEM SERVICE		DESCRIPTION
Provisioning services		
Biomass provisioning services	Crop provisioning services*	Crop provisioning services are the ecosystem contributions to the growth of cultivated plants that are harvested by economic units for various uses including food and fibre production, fodder and energy. This is a final ecosystem service.
	Grazed biomass provisioning services*	Grazed biomass provisioning services are the ecosystem contributions to the growth of grazed biomass that is an input to the growth of cultivated livestock. This service excludes the ecosystem contributions to the growth of crops used to produce fodder for livestock (e.g., hay, soybean meal). These contributions are included under crop provisioning services. This is a final ecosystem service but may be intermediate to livestock provisioning services.
	Livestock provisioning services*	Livestock provisioning services are the ecosystem contributions to the growth of cultivated livestock and livestock products (e.g., meat, milk, eggs, wool, leather), that are used by economic units for various uses, primarily food production. This is a final ecosystem service. No distinct livestock provisioning services to be recorded if grazed biomass provisioning services are recorded as a final ecosystem service.
	Aquaculture provisioning services	Aquaculture provisioning services are the ecosystem contributions to the growth of animals and plants (e.g., fish, shellfish, seaweed) in aquaculture facilities that are harvested by economic units for various uses. This is a final ecosystem service.
	Wood provisioning services	Wood provisioning services are the ecosystem contributions to the growth of trees and other woody biomass in both cultivated (plantation) and uncultivated production contexts that are harvested by economic units for various uses including timber production and energy. This service excludes contributions to non-wood forest products. This is a final ecosystem service.
	Wild fish and other natural aquatic biomass provisioning services	Wild fish and other natural aquatic biomass provisioning services are the ecosystem contributions to the growth of fish and other aquatic biomass that are captured in uncultivated production contexts by economic units for various uses, primarily food production. This is a final ecosystem service
	Wild animals, plants and other biomass provisioning services	Wild animals, plants and other biomass provisioning services are the ecosystem contributions to the growth of wild animals, plants and other biomass that are captured and harvested in uncultivated production contexts by economic units for various uses. The scope includes non-wood forest products (NWFP)[69] and services related to hunting, trapping and bio-prospecting activities; but excludes wild fish and other natural aquatic biomass (included in previous class). This is a final ecosystem service
Genetic material services		Genetic material services are the ecosystem contributions from all biota (including seed, spore or gamete production) that are used by economic units, for example (i) to develop new animal and plant breeds; (ii) in gene synthesis; or (iii) in product development directly using genetic material. This is most commonly recorded as an intermediate service to biomass provisioning.
Water supply*		Water supply services reflect the combined ecosystem contributions of water flow regulation, water purification, and other ecosystem services to the supply of water of appropriate quality to users for various uses including household consumption. This is a final ecosystem service.
Other provisioning services		

[69] See Sorrenti (2017).

ECOSYSTEM SERVICE		DESCRIPTION
Regulating and maintenance services		
Global climate regulation services		Global climate regulation services are the ecosystem contributions to reducing concentrations of GHG in the atmosphere through the removal (sequestration) of carbon from the atmosphere and the retention (storage) of carbon in ecosystems. These services support the regulation of the chemical composition of the atmosphere and oceans. This is a final ecosystem service.
Rainfall pattern regulation services (at sub-continental scale)		Rainfall pattern regulation services are the ecosystem contributions of vegetation, in particular forests, in maintaining rainfall patterns through evapotranspiration at the sub-continental scale. Forests and other vegetation recycle moisture back to the atmosphere where it is available for the generation of rainfall. Rainfall in interior parts of continents fully depends upon this recycling. This may be a final or intermediate service.
Local (micro and meso) climate regulation services		Local climate regulation services are the ecosystem contributions to the regulation of ambient atmospheric conditions (including micro and mesoscale climates) through the presence of vegetation that improves the living conditions for people and supports economic production. Examples include the evaporative cooling provided by urban trees ('green space'), the role of urban water bodies ('blue space') and the contribution of trees in providing shade for humans and livestock. This may be a final or intermediate service.
Air filtration services		Air filtration services are the ecosystem contributions to the filtering of air-borne pollutants through the deposition, uptake, fixing and storage of pollutants by ecosystem components, particularly plants, that mitigates the harmful effects of the pollutants. This is most commonly a final ecosystem service.
Soil quality regulation services		Soil quality regulation services are the ecosystem contributions to the decomposition of organic and inorganic materials and to the fertility and characteristics of soils, e.g., for input to biomass production. This is most commonly recorded as an intermediate service.
Soil and sediment retention services	Soil erosion control services	Soil erosion control services are the ecosystem contributions, particularly the stabilising effects of vegetation, that reduce the loss of soil (and sediment) and support use of the environment (e.g., agricultural activity, water supply). This is may be recorded as a final or intermediate service.
	Landslide mitigation services	Landslide mitigation services are the ecosystem contributions, particularly the stabilising effects of vegetation, that mitigates or prevents potential damage to human health and safety and damaging effects to buildings and infrastructure that arise from the mass movement (wasting) of soil, rock and snow. This is a final ecosystem service.
Solid waste remediation services		Solid waste remediation services are the ecosystem contributions to the transformation of organic or inorganic substances, through the action of micro-organisms, algae, plants and animals that mitigates their harmful effects. This is may be recorded as a final or intermediate service.
Water purification services (water quality regulation)	Retention and breakdown of nutrients	Water purification services are the ecosystem contributions to the restoration and maintenance of the chemical condition of surface water and groundwater bodies through the breakdown or removal of nutrients and other pollutants by ecosystem components that mitigate the harmful effects of the pollutants on human use or health. This may be recorded as a final or intermediate ecosystem service.
	Retention and breakdown of other pollutants	
Water flow regulation services	Baseline flow maintenance services	Water regulation services are the ecosystem contributions to the regulation of river flows and groundwater and lake water tables. They are derived from the ability of ecosystems to absorb and store water, and gradually release water during dry seasons or periods through evapotranspiration and hence secure a regular flow of water. This may be recorded as a final or intermediate ecosystem service.
	Peak flow mitigation services	Water regulation services are the ecosystem contributions to the regulation of river flows and groundwater and lake water tables. They are derived from the ability of ecosystems to absorb and store water, and

ECOSYSTEM SERVICE		DESCRIPTION
		hence mitigate the effects of flood and other extreme water-related events. Peak flow mitigation services will be supplied together with river flood mitigation services in providing the benefit of flood protection. This is a final ecosystem service.
Flood control services	Coastal protection services	Coastal protection services are the ecosystem contributions of linear elements in the seascape, for instance coral reefs, sand banks, dunes or mangrove ecosystems along the shore, in protecting the shore and thus mitigating the impacts of tidal surges or storms on local communities. This is a final ecosystem service.
	River flood mitigation services	River flood mitigation services are the ecosystem contributions of riparian vegetation which provides structure and a physical barrier to high water levels and thus mitigates the impacts of floods on local communities. River flood mitigation services will be supplied together with peak flow mitigation services in providing the benefit of flood protection. This is a final ecosystem service.
Storm mitigation services		Storm mitigation services are the ecosystem contributions of vegetation including linear elements, in mitigating the impacts of wind, sand and other storms (other than water related events) on local communities. This is a final ecosystem service.
Noise attenuation services		Noise attenuation services are the ecosystem contributions to the reduction in the impact of noise on people that mitigates its harmful or stressful effects. This is most commonly a final ecosystem service.
Pollination services		Pollination services are the ecosystem contributions by wild pollinators to the fertilization of crops that maintains or increases the abundance and/or diversity of other species that economic units use or enjoy. This may be recorded as a final or intermediate service.
Biological control services	Pest control services	Biological control services are the ecosystem contributions to the reduction in the incidence of species that may prevent or reduce the effects of pests on biomass production processes or other economic and human activity. This is may be recorded as a final or intermediate service.
	Disease control services	Disease control services are the ecosystem contributions to the reduction in the incidence of species that may prevent or reduce the effects of species on human health. This is most commonly a final ecosystem service.
Nursery population and habitat maintenance services		Nursery population and habitat maintenance services are the ecosystem contributions necessary for sustaining populations of species that economic units ultimately use or enjoy either through the maintenance of habitats (e.g., for nurseries or migration) or the protection of natural gene pools. This service is an intermediate service and may input to a number of different final ecosystem services including biomass provision and recreation-related services.
Other regulating and maintenance services		
Cultural services		
Recreation-related services		Recreation-related services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment. This includes services to both locals and non-locals (i.e., visitors, including tourists). Recreation-related services may also be supplied to those undertaking recreational fishing and hunting. This is a final ecosystem service.
Visual amenity services*		Visual amenity services are the ecosystem contributions to local living conditions, in particular through the biophysical characteristics and qualities of ecosystems that provide sensory benefits, especially visual. This service combines with other ecosystem services, including recreation-

ECOSYSTEM SERVICE		DESCRIPTION
		related services and noise attenuation services to underpin amenity values. This is a final ecosystem service.
Education, scientific and research services		Education, scientific and research services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use the environment through intellectual interactions with the environment. This is a final ecosystem service.
Spiritual, artistic and symbolic services		Spiritual artistic and symbolic services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that are recognised by people for their cultural, historical, aesthetic, sacred or religious significance. These services may underpin people's cultural identity and may inspire people to express themselves through various artistic media. This is a final ecosystem service.
Other cultural services		
Flows related to non-use values		
Ecosystem and species appreciation		Ecosystem and species appreciation concerns the wellbeing that people derive from the existence and preservation of the environment for current and future generations, irrespective of any direct or indirect use.

Note: Further explanations concerning ecosystem services marked with an '*' are provided below and in section 6.4.

6.55 *Services related to biomass provisioning*: As discussed further in section 6.4, the recording of ecosystem services in relation to cultivated production of crops, livestock and other products can be undertaken in different ways. Cultivated production processes occur along a continuum with the contribution of ecosystems ranging from high to low. In measuring ecosystem services associated with crops and wood, it is most common to measure the biomass that is harvested. An ecosystem contribution (or share) should be estimated that varies depending on the production context but, if this is not possible, a proxy measure may be used based on the gross biomass harvested. Alternatively, a range of specific ecosystem services for example pollination, local climate regulation and water flow regulation, may be measured that collectively reflect the ecosystem contribution to biomass growth. Under this second approach, the ecosystem service of crop provisioning is not recorded. Where the harvested biomass is recorded as the final ecosystem service, the various specific ecosystem services may be recorded as intermediate services.

6.56 In measuring ecosystem services associated with livestock, estimation of the ecosystem contribution should focus on the direct interaction between the livestock and ecosystems, primarily pastures. Thus, the key final ecosystem service will be grazed biomass but other services such as local climate regulation may also be relevant since ecosystems will provide a bundle of services in supporting livestock. Using this measurement approach, no estimates of livestock provisioning services should be recorded. If livestock provisioning services are recorded, for example based on weight gain or outputs of milk and eggs, it is essential that an ecosystem contribution is measured since, especially in intensive farming systems, there may be very little direct connection with ecosystems in rearing livestock.

6.57 *Services related to water supply:* As discussed further in section 6.4, ecosystem services related to water supply, for example water flow regulation and water purification, may be measured distinctly as separate final ecosystem services or measured as a combined ecosystem service using water supply as a proxy measure to reflect the overall ecosystem contribution.

6.58 *Services related to amenity:* Amenity related services arise in the context of benefits people obtain from living or working in a specific location. They are most usually considered in relation to specific characteristics of a place of residence. In the ecosystem service reference list, a number of services are considered to contribute to a location's amenity including visual amenity services, recreation-related services and noise attenuation services. Where possible, each of these should be measured distinctly but measurement of a combination of amenity related services may be required in practice.

6.59 *Recording final and intermediate services:* The descriptions in the reference list provide indications as to whether an ecosystem services would be expected to be recorded as final or intermediate, recognising that in practice the specific context will be the determining factor. Generally, it is expected that outside of the context of biomass provisioning, most ecosystem services will be recorded as final ecosystem services. There may be some other contexts in which a connection between ecosystem services can be identified, for example, the role of nursery and habitat maintenance services supporting recreation-related services in tourism areas, but it is not expected that many intermediate services would be recorded as a matter of standard practice.

6.3.3 The link between biodiversity and ecosystem services

6.60 The SEEA EA adopts the CBD definition of biodiversity[70] which recognises ecosystem, species and genetic diversity as the broad components of biodiversity. These components of biodiversity are not considered ecosystem services in themselves but there are distinct elements within these components that can be directly linked to ecosystem service supply. For example, specific genes (DNA sequences) can be a provisioning service to the pharmaceutical industry; pollinator species can provide important pollinating services to the agricultural sector; certain plant species can support the development of medicines (a provisioning service); the presence of well-known species (e.g., lions and elephants) can underpin recreation-related services; and ecosystems, such as forests and beaches, can provide places for recreation. A diversity of genes, species and ecosystems thus provides a greater range of ecosystem service options.

6.61 More broadly, the interactions between different components of biodiversity are essential for cycling energy, nutrients and other materials through the environment (Mori et al., 2013). This is fundamental for maintaining the various ecosystem processes and functions that underpin ecosystem service supply (Bolt et al., 2016). Further, as biodiversity is lost, these ecosystem processes may be impacted. For example, as different ecosystems are lost, ecosystem processes are altered at landscape scale; and as species and their populations are lost from ecosystems, so are the different functional roles they perform (e.g., decomposing, pollinating, dispersing seeds). Consequently, biodiversity loss directly threatens ecosystem processes and the supply of many ecosystem services across multiple scales.

6.62 Biodiversity also plays a fundamental role in maintaining the ability of ecosystem assets to supply ecosystem services in the future. The presence of a diversity of organisms (e.g.,

[70] See Chapter 2 for reference.

multiple species, the genetic diversity within them) performing a given function within an ecosystem boosts the ability of that ecosystem asset to maintain functionality and supply ecosystem services. This is because different environmental changes or shocks will affect individual elements of this diversity in different ways. This ability of ecosystems to tolerate shocks and disturbances while maintaining the same level of functioning is often referred to as ecosystem resilience, see for example, Mori et al. (2013), Thompson et al. (2009), Walker (2019), and may be considered to have an 'insurance value' (Baumgärtner, 2007).

6.63 Elements of biodiversity that do not provide ecosystem services at present may also provide valuable ecosystem services in the future. For example, a tropical tree species might prove to be the only source of a drug capable of combating a major new human disease. This role of biodiversity can be linked to the concept of an "option value" (Faith, 2018; Weitzman, 1992).

6.64 The existence of biodiversity and the desire for its ongoing preservation is also connected to non-use values that people hold with respect to the environment. These include existence and bequest values. Section 6.3.4 discusses non-use values.

6.65 The connections between biodiversity and human activity operate in two directions. Thus, in addition to biodiversity supporting the supply of ecosystem services, biodiversity itself will be impacted by the type of use made of ecosystems for example in terms of harvesting practices for timber and fish and the extent of tourism activity. Choices concerning restoration and protection activity will also have impacts on biodiversity.

6.66 There still remains considerable uncertainty around the specifics of the relationships between biodiversity and ecosystem service supply (P. A. Harrison et al., 2014; Mace et al., 2012). In particular, where 'tipping points' or boundaries for biodiversity loss may lie with respect to ecosystem service supply (Mace et al., 2015). This should encourage a precautionary approach to the management of biodiversity for sustainable ecosystem service supply. This aspect is relevant in the consideration of ecosystem capacity discussed in section 6.5.

6.67 More generally, it will not be the case that increases in biodiversity will be necessarily reflected in increases in flows of individual ecosystem services. For some ecosystem services, for example relating to biomass provisioning, it is likely that increasing ecosystem service flows will be correlated with declines in biodiversity. Since the relationship between biodiversity and individual ecosystem services will vary, care should be taken in making assumptions about the anticipated changes in the direction of ecosystem service flows related to different levels of biodiversity.

6.68 The strong emphasis on biological "variability" or "diversity" is clear in the CBD definition. In the context of ecosystem accounting, biodiversity can then be viewed as an emergent property of a set of ecosystem assets and the community assemblages within them. These ecosystems and communities interact and support multiple ecosystem processes that underpin the capacity for current and future ecosystem service supply. As such, the link between biodiversity and ecosystem service supply should consider the roles played by diversity across all three of its components (ecosystems, species and genes) and across scales.

6.3.4 The treatment of non-use values

6.69 From an economic perspective, the relationship between people and the environment is commonly characterised as comprising both use and non-use values as described in the Total Economic Value framework (Pearce & Turner, 1990). The recording of use values, i.e., values arising where the benefit to people is revealed through their direct, personal interaction with the environment (e.g., harvesting food, hiking in forests, benefitting from cleaner air), or through indirect use (e.g., regulation of water flows providing flood mitigation) into an accounting framework is relatively straightforward in concept and is the focus of measurement in the SEEA EA.

6.70 The treatment of non-use values in an accounting setting requires additional considerations. In the context of the environment, non-use values are those values that people assign to ecosystems (including the associated biodiversity), irrespective of whether they use (directly or indirectly), or intend to use, the ecosystems. Two main types of non-use values are described: bequest value where the value is based on ensuring the ecosystem is available to future generations; and existence value where the value is based on the knowledge that the ecosystem is present now. In both cases, the benefit of the non-use value accrues to an individual in the present day. Hence, for accounting purposes, the two values have the same treatment.

6.71 In the discussion of use and non-use values there is also discussion of option values. From an accounting perspective, these are considered a type of use value to the extent that the underlying motivation for these values is to ensure that ecosystems are able to provide ecosystem services in the future, including ecosystem services that may be currently unknown or not used. Option values thus capture situations in which ecosystems are not currently being used but this is different from the concept of non-use. Conceptually, option values will be associated with measures of ecosystem condition and biodiversity and with measures of the expected future flows of ecosystem services incorporated in measures of the net present value of ecosystem services.

6.72 Unlike flows of ecosystem services, there is no direct or indirect interaction with the environment associated with non-use values. Consequently, while non-use values require that ecosystems exist and may be associated with flows of environmental knowledge or information, it is not considered, from an accounting perspective, that a transaction has taken place consistent with the framing used for recording ecosystem services in the SEEA EA.

6.73 Nonetheless, this type of connection to the environment is of considerable importance and therefore a separate type of flow has been included in the Ecosystem Services reference list - ecosystem and species appreciation. This is to allow compilers to record data that can be directly associated with non-use values. For example, it may be relevant to record data on the presence or abundance of iconic species. Further, estimates of non-use values in monetary terms may be of particular policy interest. These values can be presented in complementary valuations as discussed in Chapter 12.

6.3.5 The treatment of ecosystem disservices

6.74 Consistent with the accounting treatment of transactions, the recording of ecosystem services includes positive exchanges between ecosystem assets and economic units in a sense of contributing to benefits. This does not imply that all outcomes arising from transactions are necessarily all positive (e.g., the purchase of cigarettes can lead to poor health outcomes) or that all transactions are similarly motivated (e.g., some purchases such as fire alarms are made to limit potential negative consequences). However, the transactions themselves all involve exchanging positive quantities of a good or service.

6.75 There is a range of contexts in which the outcomes of interactions between economic units and ecosystem assets are negative from the perspective of the economic units. Examples include the effects of pests on crop production, increases in disease from environmental vectors, such as mosquitoes or zoonotic episodes, and the presence of flies at a social event. Collectively, these have been labelled ecosystem disservices. From an economic perspective, it appears natural to deduct these flows from the positive ecosystem services to estimate the "net" connection between people and ecosystems.

6.76 However, from an accounting perspective, although it is possible to record relevant physical flows and quantities such as the number of pests, or the number of people affected by malaria, none of these negative connections can be considered to reflect an exchange of positive quantities of a good or service and hence are not considered as transactions for accounting purposes. Further, the precise nature of the net connection at a societal level must recognise that different people may have different values with respect to the same ecosystem asset (e.g., trees that provide shade may also obstruct some people's view).

6.77 While these flows are not transactions, the negative effects of ecosystem disservices can be reflected in accounting entries and related to ecosystem assets. Two main contexts can be considered. First, the negative effects may be reflected in reduced flows of ecosystem services – e.g., reduced biomass provisioning services because of invasive pests. In this case, the extent of the negative effect may be determined by using the accounts to compare two different scenarios – e.g., with and without pests. This is an analytical step rather than an accounting entry.

6.78 Second, the impacts of disease and other effects on human health, can, in broad accounting terms, be reflected in a loss of human capital which in turn may be reflected in reduced production (e.g., days lost due to poor health). Again, analysis would be required to determine the extent of the contribution of the ecosystem disservice relative to other factors.

6.79 Thus, while the accounting approach does not allow for direct recording of ecosystem disservices, it does provide a framework for the analysis of their effects. Further, the same approach can be applied in the context of analysis of negative environmental externalities, such as emissions from peatlands, where the flows relate to the activities of economic units rather than being ecological in origin. For example, the loss of ecosystem services – such as global climate regulation services, arising from peatland emissions will be recorded in the accounts and there is potential for any health effects arising from the clearing of peatlands (e.g., linked to related forest fires and smoke) to be shown in a loss of human capital.

6.80 While the welfare effects themselves are not fully incorporated in accounting entries, the data from the accounts can underpin the assessment of their magnitude. This topic is discussed further in Chapter 12 where complementary accounting tables show how estimates of the monetary value of the externalities can be presented in a supply and use table format for both ecosystem disservices and negative environmental externalities.

6.4 The treatment of specific ecosystem services and other environmental flows

6.4.1 The treatment of biomass provisioning services

6.81 There is clear recognition that people source and use biomass from ecosystems in a wide variety of ways and for different purposes, including for food, fibre and energy. Sometimes biomass is harvested directly by a final consumer (e.g., subsistence production, households picking berries in a forest) but the majority of biomass is grown, harvested or accessed by farmers, foresters and fishers (economic units both small and large) that supply it to other economic units. Determining the appropriate treatment of the integral biomass provisioning services is complicated by the variety of biomass types and the range of ways in which people grow and harvest biomass from the environment.

6.82 Biomass provisioning services are ecosystem contributions to SNA benefits which take the form of food, feed, fibre and energy outputs produced and consumed by economic units. In line with treatments in the SNA, all biomass provisioning that is input to subsistence production of agriculture, forestry and fisheries should be included in the scope of ecosystem accounts. This includes for example the collection and harvest of non-wood forest products and the growing of vegetables in backyard gardens.

6.83 While all biomass harvested is considered an SNA benefit, the recording of these flows in the SNA makes a distinction between cultivated and natural (non-cultivated) production processes based on the extent to which an economic unit manages or controls the growth of the biomass. The range of natural and cultivated production processes recorded in the SEEA EA aligns with the scope of activity recorded in the SNA.

6.84 In natural production processes, all of the biomass that is harvested is considered the ecosystem contribution. Examples include harvesting of timber from natural forests, capture fishing from wild fish stocks and wild animals trapped and hunted (including bush meat). The measurement of the ecosystem service should be aligned with the gross quantity of biomass that is harvested, i.e., the gross natural resource input, following the SEEA Central Framework (section 3.2.2). This will be different from the total stock of biomass available for harvest and different from the biomass that is used in a subsequent production or consumption process. Thus, for example, felling residues and discarded catch should be considered as part of the ecosystem service flow. This treatment applies irrespective of (i) the length of time over which the biomass has been growing; and (ii) the nature of the product, (e.g., the gross biomass harvested includes honey from wild bees). Thus, focus is solely on the quantity of the biomass that is harvested or accessed since this reflects the total use (or input) of the ecosystem's resources. The services associated with the biomass from natural production processes are recorded during the accounting period in which they are harvested or accessed.

6.85 In cultivated production processes, joint production is considered to occur where the role of the ecosystem in supplying the biomass intersects with the activity (and associated human inputs, e.g., labour and produced assets) of people and economic units. The activities of economic units in this joint production process can be separated into those concerning the growth of the biomass (e.g., the application of fertilizers and pesticides) and those concerning the harvest of the biomass. The contribution of the ecosystem occurs up to the point of harvest.

6.86 There is a very wide range of cultivated production contexts. Thus, the extent of human activity in the management of biomass growth can be very high (e.g., for hydroponically grown strawberries) or very low (e.g., for lightly managed native forests). Depending on the type of biomass and the related product, the timing and context of the growth and harvest can vary significantly. Further, within each production context there is a wide variety of management practices and there may be more than one benefit that is generated. For example, the general activity of corn production may produce food as well as biomass for the production of energy; and cattle production will supply food as well as hides for leather and bones for fertilizer.

6.87 Notwithstanding this diversity of cultivated production contexts, the conceptual intent for ecosystem accounting is to identify the ecosystem contribution, i.e., to recognize that in different production contexts the relative role of ecosystem services will vary. The measurement of the ecosystem contribution in different contexts can be considered in two distinct ways. One approach uses the biomass harvested as the measurement focus for identifying the overall ecosystem contribution, and the other focuses on the various types of ecosystem contributions such as those concerning nutrients, water, soil retention, pollination etc. which will be used in different combinations in different contexts.

6.88 Under the first measurement approach, particularly when cultivated production is of high intensity, there may be a significant difference between the ecosystem contribution and the gross biomass harvested (Cerilli et al., 2020). This difference may increase due to, for example, additional fertilizer, enhanced seed varieties and intensified management even while the extent of the ecosystem asset under use decreases (e.g., through conversion to settlements). Biotic elements that contribute positively to biomass growth may also deteriorate (e.g., humus content). Compilers are thus encouraged to estimate the ecosystem contribution to cultivated biomass production processes especially where these might be changing over time.[71]

6.89 In practice, there is a considerable measurement challenge in either identifying all of the relevant individual ecosystem inputs or accurately measuring the ecosystem contribution to the gross biomass that is harvested in a way that reflects the diversity of cultivated production contexts and covers all types of biomass. Consequently, where the relative contribution cannot be estimated, the gross biomass harvested may be used as an adequate proxy measure for the flow of biomass provisioning services in cultivated production contexts, irrespective of the extent of human inputs and the intensity of management.

6.90 Whether the ecosystem contribution is measured directly or not, it is recommended that additional information is provided on the cultivated production contexts including, for example, data on the gross biomass harvested in intensive and extensive production contexts or via organic farming. Further, measurement by biomass type and by relevant ecosystem characteristic (e.g., by soil type, climatic zone), and data on variables such as soil fertility, soil-water availability and fertilizer use is likely to assist in better understanding the relative ecosystem contribution. Such information may also be used to support estimation of the ecosystem contribution, for example by comparing yield levels between intensive and extensive or organic farming systems.

6.91 Under the second measurement approach, each relevant ecosystem service is measured directly with the intent to provide sufficient coverage of specific services such that the overall ecosystem contribution to the production of biomass is appropriately reflected. It is noted that under the first measurement approach these specific ecosystem services, such as pollination, may also be recorded but they are shown as intermediate services.

6.92 In line with SNA time of recording treatments, ecosystem services in cultivated production contexts are recorded progressively over the life of the biomass. Thus, services associated with timber production from plantation forests should be recorded progressively as the timber resources grow in line with the recording of the growth of this resource in the national accounts as a work in progress. Where multiple types of biomass are harvested from a single ecosystem asset over the course of an accounting period (e.g., through cultivation of summer and winter crops), all biomass harvested should be attributed to the same ecosystem asset.

6.93 Both the measurement of the ecosystem contribution and the gross harvested biomass require a clear measurement target. A different measurement target is used for plants and livestock. For cultivated plants, the ecosystem services are measured in relation to the quantity harvested, for example quantities of corn, timber or apples. This flow is recorded as supplied by the relevant ecosystem and used by the economic unit managing the cultivation (e.g., farmer).[72]

6.94 For cultivated livestock, the measurement target is on the extent of the connection between the livestock and relevant ecosystem assets, primarily natural and cultivated pastures.

---

[71] Methods have been developed for this purpose including input-output datasets, agronomic and agricultural production functions and energy/energy-based approaches. An example can be found in Vallecillo et al. (2019, Chapter 3) where an energy-based ratio is applied to assess ecosystem contribution and separate it from human input.

[72] The subsequent sale of harvested outputs by the economic unit along the supply chain is recorded in the standard SNA production accounts. Double counting is avoided by ensuring that there are entries for both the supply and use of the ecosystem service and hence the net effect with respect to the farmer's value-added is unchanged but the contribution of the ecosystem is recognised.

Depending on the cultivation context, there may be some disconnect between ecosystems and the production of livestock and livestock products. Therefore, where the livestock production process does not involve direct connection with an ecosystem, as occurs, for example, in some forms of intensive chicken, cattle and pig rearing, no ecosystem services should be recorded. In these cases, the associated ecosystem services are limited to the ecosystem contribution to the production of feed and supplements (e.g., via hay, soybean meal, pellets, etc.) which would be recorded as crop provisioning services.

6.95 To ensure focus on the ecosystem contribution, it is recommended to measure the grazed biomass provisioning services as the primary ecosystem contribution. Other ecosystem contributions such as water supply and local climate regulation (e.g., trees providing shade and wind protection to livestock) may also be incorporated. These various contributions are recorded as final ecosystem services and no distinct livestock provisioning services should be recorded. It is also possible to measure livestock provisioning services reflecting the weight gain in livestock or the production of products such as milk and eggs. However, in these cases it is essential to estimate an ecosystem contribution since, especially in intensive farming systems as noted above, there may be very little direct connection with ecosystems in rearing livestock.

6.96 By extension, the livestock treatment applies to other animals (mainly fish) raised in aquaculture facilities (both marine and freshwater) whose cultivation involves the provision of feed inputs, including fish meal. Thus, the gross biomass harvested from aquaculture should not be used as a proxy for the ecosystem contribution. An exception arises where no feed or other inputs are provided (e.g., the farming of oysters). In these cases, the ecosystem service can be appropriately measured using the gross biomass harvested. Where aquaculture is undertaken without a direct connection to a surrounding ecosystem asset, no ecosystem services should be recorded.

6.97 To complete the description of the treatment of biomass provisioning services, four other commonly considered issues are noted.

- *Links to cultural services.* There are many instances in which the harvesting of biomass occurs in a recreational or cultural context. For example, people catch wild animals, especially fish, as part of their recreational activities and there may be traditional harvests undertaken by indigenous groups. If the harvest is retained for subsequent consumption, then the quantity of the associated biomass should be included as part of biomass provisioning services. At the same time, there will be a connection to the measurement of cultural services. In these instances, flows of cultural services should be recorded in addition to biomass provisioning services.

- *Services related to wild fish provisioning services.* For cultivated biomass provisioning services, it should be conceptually straightforward to attribute the service to a specific ecosystem asset since there will be a distinct location where the biomass is grown and harvested. For uncultivated biomass provisioning this may be more challenging, especially for fish biomass. In concept, for wild fish biomass, the relevant supply location is the place at which the interaction with the ecosystem occurs – i.e., the place where the catch occurs. However, it is well recognized that there may be multiple ecosystems that are important in the growth of wild fish. To record their relative importance, intermediate services can be recorded reflecting the connections between ecosystem assets. This would include, for example, recording nursery services from seagrass meadows for certain species. The extent to which this measurement is possible will depend on the data available and levels of ecological knowledge.

- *Trade in biomass products.* Given the extent of international trade in agricultural, forestry and fisheries products, there will commonly be a large spatial disconnect between the location of harvest (where the ecosystem service is recorded), the location of subsequent processing and manufacturing, and the location of final household consumption. As explained further in Chapter 7, following accounting principles, the supply and use of ecosystem services is recorded in the location of harvest rather than recording the supply of ecosystem services in one location and use (albeit embodied in another product) in another location. Thus, there is no international trade in biomass provisioning services to be recorded. It is possible using input-output techniques to trace the flow of associated/derivative products within the international economy, for example to derive ecosystem service footprints.

- *Losses in biomass production.* A common feature in the harvesting of biomass is that not all of the harvested biomass is retained and used in the subsequent production process. These are referred to in the SEEA Central Framework as natural resource residuals and include felling residues, discarded catch and harvest losses. In the SNA, the focus is on the output ultimately sold by the producer and thus, in physical terms, the measure of output will be net of these losses. In the SEEA Central Framework, compilers are encouraged to record the flows in gross terms (SEEA Central Framework, section 3.3.2), since this reflects the actual flow of inputs from the environment. For ecosystem accounting, it is recommended that the principles of the SEEA Central Framework should be applied such that quantity of biomass provisioning services should be equal to the harvest in gross terms, i.e., before harvest losses, felling residues and discarded catch are deducted. Even though they are not finally used by economic units, in terms of progressing through the supply chain, they do represent contributions from the ecosystem into the production process.

6.4.2 The treatment of water supply

6.98 The treatment of the abstraction of water by economic units, including households, for use in production processes (e.g., irrigation, cooling) or for consumption, lies on the ecosystem service measurement boundary. There is no doubt that flows of water are highly relevant in both ecological and economic contexts, with the volume of water supply being largely determined by hydrological cycles. At the same time, the availability and quality of water in any given location is directly affected, to varying degrees, by ecosystem structures and processes. Consistent with the general definition of ecosystem services, it is the ecosystem contribution that is the primary focus of measurement in ecosystem accounting.

6.99 In ecological terms, there is a range of factors that contribute to the availability and quality of water. Two primary processes are (i) those related to the regulation of base flows of water including precipitation, runoff, infiltration and evapotranspiration leading to water absorption and release; and (ii) those related to the purification of water. In a catchment context, these and other relevant ecological processes are likely to involve multiple ecosystem assets of varying types within a catchment, e.g., forests, cropland, wetlands and rivers. These ecological processes can be considered inputs to water supply.

6.100 In compiling ecosystem accounts there are a number of flows that should be recorded in order to best reflect the relevant ecosystem contribution. First, a distinction should be made between different purposes for water abstraction. In particular, a distinction should be made between abstraction that is less dependent on the quality of the water abstracted, for example, water used for cooling, hydroelectric power generation or desalination, and cases where the quality of water is an important factor, e.g., for domestic consumption. Making this distinction allows the relevant ecosystem contributions to be appropriately targeted; e.g., water purification services will not be relevant inputs for non-quality dependent water abstraction.

6.101 Second, if the abstraction of water from the environment does not require or involve an ecosystem contribution it should be recorded as an abiotic flow, equal to the volume of water abstracted for those purposes. This would include, for example, the collection of rainwater in tanks.

6.102 Third, where ecosystem contributions are involved, ideally, these contributions should be measured directly and recorded as final ecosystem services. This may involve recording flows of water purification services and water flow regulation services, for example. Where this direct measurement is possible, the actual flows of water abstracted should be recorded as abiotic flows, equal to the volume of water abstracted for those purposes.

6.103 Finally, if the direct contributions to water supply cannot be separately recorded, it is appropriate to record the volume of water abstracted as a proxy for the ecosystem contributions. This flow should be recorded as a final ecosystem service. If this measurement approach is adopted, there should be no entry for abiotic flows relating to these volumes of water.

6.104 To support comparability across sets of accounts, irrespective of the measurement approach adopted, all flows of abstracted water should be recorded in the ecosystem accounts either as ecosystem services or as an abiotic flows. Further, the recording of flows of surface and groundwater water abstraction should align with the definitions and treatments of the SEEA Central Framework, section 3.5 – Physical flows accounts for water.

6.105 A significant volume of water is abstracted from groundwater sources from both deep and shallow aquifers. The same treatments as outlined above also apply to groundwater. Water abstracted from marine ecosystems, for example for desalination or use as cooling water, should be treated as an abiotic flow, following the treatment outlined above.

6.106 Following the SEEA Central Framework, water used for hydroelectric power generation is treated as abstracted – i.e., it is considered removed from the environment into the economy, notwithstanding its immediate return and potential to affect water quality. Water abstracted for hydroelectric power generation will commonly be treated as an abiotic flow although in some contexts, surrounding landscapes may provide ecosystem services that support hydroelectric power generation, for example, through sediment retention. In these contexts, the treatment outlined above can be applied.

6.4.3 The measurement of global climate regulation services

6.107 The measurement and analysis of climate change commonly focuses on the emission of greenhouse gases (GHG) as a result of economic and human activity and the associated changes in concentration of these gases in the atmosphere. Ecosystem accounting has a complementary focus of measurement on the role of ecosystems in mitigating climate change through their ability, primarily, to remove carbon from the atmosphere and to store carbon. Global climate regulation services thus reflect the ecosystem contributions to reducing concentrations of GHG in the atmosphere and stabilizing the climate, in turn avoiding damages that arise due to climate change. The measurement approach described here focuses on carbon since this GHG is absorbed from the atmosphere by plants and sequestered in ecosystems. It is recognised that some types of ecosystems can also be a source of GHG (CO_2, CH_4 and N_2O), often but not necessarily related to ecosystem degradation.

6.108 The approaches described here to accounting for the role of ecosystems in global climate regulation are based on the comprehensive recording of stocks and changes in stocks of carbon (i.e., a physical carbon stock account). Ideally, this will encompass measurement of the opening and closing stocks of carbon stored in biomass (both above and below ground), debris and in soil and sediment, across the full range of ecosystem types within an ecosystem accounting area, including marine ecosystems as appropriate.[73] Changes in the carbon stock will reflect the removal of carbon from the atmosphere and the loss of carbon from these stocks for all reasons, including for example, timber harvest, reforestation activity, conversion of peatlands to agricultural production, natural decomposition of organic material and the effects of wild fires.

6.109 The measurement of global climate regulation services does not require measurement of all stocks and changes in stocks of carbon, as the scope is restricted to biocarbon. For example, data are not required concerning deposits of fossil fuels, emissions of carbon through the consumption of fossil fuel, or the accumulation of carbon in the atmosphere. Nonetheless, a complete accounting for all carbon stocks and flows is highly recommended to support coherence in measurement and wider discussion on climate change and associated policy issues. Chapter 13, section 13.4, provides further discussion on accounting for carbon in supporting the discussion of climate change.

6.110 In the SEEA EA, the measurement of the global climate regulation services considers two components, carbon retention and carbon sequestration. The carbon retention component reflects the ability of ecosystems to accumulate and retain the stock of carbon – i.e., ecosystems supply a service through the avoided emission of carbon to the atmosphere. Thus, to the extent that the carbon stock held by ecosystems decreases (e.g., due to ecosystem conversion from forest to cultivated land), then the quantity of services provided will decrease. The reverse also holds, that is, increases in stock will lead to a rise in carbon retention services over time.

6.111 The carbon retention component of the service is quantified by recording the stock of carbon retained in ecosystems at the beginning of the accounting period (i.e., the opening stock). This is a proxy indicator for the flow of the service, analogous to the quantification of the services supplied by a storage company in terms of the volume of goods stored.

6.112 The total stock of carbon is very large, especially in some ecosystem types such as peatlands. By convention, the measurement scope of the carbon stock for the derivation of the measure of carbon retention is limited to carbon stored in above ground and below ground (including sea bed) living and dead biomass in all ecosystems and soil organic carbon. In the case of peatlands and relevant organic carbon rich soils, only the carbon stored to a maximum of 2 metres below the surface should be included. Inorganic carbon stored in freshwater, marine and subterranean ecosystems is excluded from scope. Within this measurement boundary, for a single ecosystem, the minimum service that can be supplied is zero when the stock of carbon (measured using the scope just described) is zero, i.e., no carbon is retained.

6.113 The carbon stored in fossil fuel deposits should not be considered an ecosystem service since these deposits are not part of ecosystem assets. Similarly, the storage of carbon in harvested wood products should not be considered an ecosystem service since this carbon is no longer stored as part of an ecosystem asset, but rather within products (e.g., houses, furniture) that are considered part of the economy. As well, carbon stored in stocks of cultivated biological resources (e.g., crops, livestock) should not be included in the measurement of carbon retention due to its short rotation cycle.

[73] This scope is broader than required according to the reporting requirements of the UNFCCC which focus on anthropogenic emissions (proxied by assessing the emissions from managed lands). See also IPCC 2006 Guidelines and their 2019 revision (https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html).

6.114 The carbon sequestration component of the service reflects the ability of ecosystems to remove carbon from the atmosphere. In measuring this component, it is assumed that carbon sequestration concerns only carbon that is expected to be stored for long periods of time. This may involve storage within an ecosystem asset, e.g., a mangrove or wetland, or another form of storage (e.g., in the economy). Carbon that is sequestered but not expected to be stored, e.g., crops, should be excluded from scope. An appropriate metric is the net ecosystem carbon balance. Where net carbon sequestration is zero or negative, the level of service supplied by an ecosystem will be zero. There is a link between the measurement of carbon sequestration (reflecting an increase in the carbon stock) and carbon retention (reflecting the level of the stock). However, since in most cases sequestration in any single year will represent a small fraction of the stock of carbon retained, they are considered for accounting purposes to be related but distinct contributions to the global climate regulation service.

6.115 In principle, carbon retention and carbon sequestration components should be measured for all ecosystem assets. In practice, it is likely that different ecosystem assets will provide different contexts for measurement. In stable ecosystems, carbon retention will be the primary component, while in those ecosystems where there is clear expansion in the stock of carbon, carbon sequestration may be the focus of measurement. Of high relevance will be ecosystems whose stock of carbon is at risk of emission, for example due to land use practices (e.g., draining of peatlands, deforestation) or extreme events (e.g., fires). In these cases there may be little carbon sequestration and the focus of measurement should be placed on measuring carbon retention.

6.4.4 The identification of cultural services

6.116 There are important connections between people and ecosystems that are not provisioning or regulating in nature. The label cultural services is used to encompass many of these experiential and non-material connections. This label is a pragmatic choice and reflects its longstanding use in the ecosystem services measurement community. It is not implied that culture itself is a service, rather it is a summary label intended to capture the variety of ways in which people connect to, and identify with, nature and the variety of motivations for these connections.

6.117 There are two key considerations in the identification of cultural services for ecosystem accounting purposes. First, it is necessary to determine the relevant set of benefits since these services can only be defined from a user perspective. Second, flows of cultural services, representing the contribution of the ecosystem to the benefits, will reflect the characteristics and qualities of ecosystems. For many cultural services, recognizing the richness and functionality of the space provided by ecosystems, for example to support recreation, is fundamental.

6.118 For ecosystem accounting, the cultural benefits to which cultural ecosystem services contribute comprise (i) benefits from undertaking activity (including recreation) within ecosystems (i.e., in situ) and (ii) benefits from having a cultural, spiritual, artistic or similar relational connection to an ecosystem or the biodiversity it contains. The first type of cultural benefits in which people experience nature directly is considered to encompass a contribution from the ecosystem, accepting that there must also be human inputs of time and potentially resources (e.g., equipment, travel). Both types of benefits will encompass associated benefits to people’s physical and mental health.

6.119 The second type of cultural benefits arise from a wide variety of motivations and may reflect both use and non-use values. This type of benefit includes cultural and spiritual connections and may commonly be a focus of economic transactions, such as donations to non-profit groups that are motivated to protect and conserve ecosystems.

6.120 For accounting purposes, cultural benefits arising from the remote experience of ecosystems (including via various media – e.g., television, music, photos, etc.) are excluded from scope. There remain within scope, a more limited set of benefits and associated services used by those who directly experience the characteristics and qualities of the ecosystems (e.g., artists, movie producers, etc.) and who, in some instances, may be required to pay for access or similar rights to secure the benefits enjoyed by others remotely.

6.121 Given this scope of cultural benefits, cultural services are defined as the perceived or realized qualities of ecosystems whose existence and functioning enables a range of cultural benefits to be derived. Within this definition, cultural ecosystem services (i) reflect the ecosystem contribution in terms of providing places and opportunities for activity by people; (ii) are linked to flows from ecosystems to people that may be considered "experiential"; and (iii) are able to contribute to multiple benefits, i.e., one ecosystem and its characteristics/qualities can contribute to different cultural benefits and can be linked to varying motivations of different users.

6.122 Using this definition of cultural services, four cultural services are included in the reference list, namely: recreation-related services; visual amenity services; education, scientific and research services; and spiritual, artistic and symbolic services. A separate class - ecosystem and species appreciation - has also been included in the reference list to allow for recording data on non-use values (see section 6.3.4). A description of these services is provided in Table 6.3 above. In recording these services, consideration should be given to the potential connections among them given that a single interaction (e.g., visit to a park) could potentially be recorded as reflecting a range of different services. In such cases, attribution should be made based on the primary purpose or motivation of the interaction.

6.123 Cultural ecosystem services contribute to processes involving different combinations of ecosystem assets, produced assets (e.g., access roads, on-site facilities, walking trails, residential location) and human capital (including people's time, experience and knowledge, capabilities (physical and perceptive)). Generally, human inputs will reflect the inputs required to use or access the cultural benefits, but some human inputs, for example concerning activities to restore or maintain ecosystem condition, will concern the supply of cultural benefits.

6.124 People undertake a range of activities in the environment for a range of purposes. Generally, the focus of cultural services is on activities of a recreational or personal purpose. However, for those people working outdoors – such as farmers, tour guides, landscapers and others that have a relatively direct connection with the environment in their jobs – they will likely derive some benefit from being outdoors that is similar to a recreation-related service. The potential ecosystem contributions to these benefits are not recorded explicitly in the ecosystem accounts but, where they arise (which will not be the case in all outdoor labouring contexts), estimates should be included in measures of visual amenity services.

6.125 Where payments are made by people to economic units who manage ecosystems, e.g., managers of national parks, for access to ecosystems; or where payments are made to economic units who support activities in ecosystems (e.g., canoe rental businesses), connections can be made to entries in the standard national accounts.

6.4.5 *The treatment of abiotic and other environmental flows*

6.126 As introduced in section 6.2.5, there is a range of flows between the environment and the economy in which there may be discussion as to whether there is a material ecosystem contribution that should be recorded as an ecosystem service. In general terms, if there is a clear contribution of ecological characteristics and processes, then the flow can be treated as an ecosystem service. However, if there is no distinct role, the flow is treated as an abiotic flow. This distinction is clear in many cases but there are also a range of boundary cases. As described in section 6.2.5, there are a number of types of abiotic and other environmental flows and it is useful to consider the various boundary cases.

6.127 The treatments described here are intended to give guidance to compilers as to the appropriate treatment to support comparability of accounts. However, it is not possible to conceive all possible contexts. Thus, in principle, compilers should return to the definition of ecosystem services (para. 6.9) and ensure that the focus of measurement is on the ecosystem contribution to benefits. Further, in identifying ecosystem services the focus should be on the nature of the ecological characteristics and processes rather than on whether the ecosystem is more or less dominated by biotic or abiotic components, i.e., recognizing that deserts, with comparably little biota, and rainforests, with much biota, are both ecosystem types. Since by definition, ecosystems are a combination of both biotic and abiotic components, and involve interactions across various scales, this variation in ecosystem types should not be a key factor in determining whether an ecosystem service is supplied and used.

6.128 Compilers are encouraged to record abiotic and other environmental flows where relevant to the analysis of ecosystem use since there are commonly trade-offs between ecosystem services and these flows. This is particularly the case for geophysical services, including flows of water, wind and solar energy. In recording flows in biophysical terms, there is no defined aggregate of ecosystem services and hence the inclusion of additional entries concerning abiotic flows in relevant tables does not impact on recorded aggregates. However, where monetary valuation is undertaken (following the advice in Chapters 8-10), abiotic flows should not be included in the measurement of the value of ecosystem assets. The value of abiotic and other environmental flows may commonly be able to be measured using observed market prices and the net present value of these flows can be recorded alongside the value of ecosystem assets in the extended balance sheet described in Chapter 11.

6.129 <u>Flows related to abiotic components of ecosystems in the supply of regulating and maintenance services.</u> Since, ecosystems are a combination of biotic and abiotic components, the following cases are treated as ecosystem services, notwithstanding that there may be a dominant role of abiotic components in some ecosystem types.

- Air filtration services (capture of air pollutants) by abiotic components (such as bare and rocky surfaces) – here pollutants are absorbed but not by active biotic components.
- Coastal protection services provided by unvegetated shingle or sand dunes – here the predominant role of abiotic components in the landscape structure in providing the services is recognised.
- Water purification and regulation services from bare but unsealed soil – here water permeating through the soil may be improved in quality through water purification services and may also provide a more continuous supply of water to groundwater sources.

6.130 <u>Flows related to the generation of energy.</u> For flows of energy from non-renewable sources, such as fossil fuels and uranium, it is considered that these are abiotic flows from geological resources. Where peat is used as an energy source, this extraction should be recorded as an abiotic flow.[74]

6.131 For flows of energy from renewable sources, three types can be distinguished:

- Energy from biomass, including round and brushwood, maize used for ethanol, etc. Here the flow involves an ecosystem contribution that should be captured as part of estimating the flow of biomass provisioning services.
- Energy from sources such as wind, solar, geothermal and tidal energy. Here the flows involve geophysical processes and hence they are considered abiotic flows from geophysical sources.
- Energy from hydroelectric power generation. For ecosystem accounting, it is considered that the source of the energy is related most strongly to the landscape structure and geomorphology (for example, the fall in the river). Thus, while ecosystem services supplied by the surrounding landscape such as water regulation of base flows and soil erosion control are important final ecosystem services to be recorded, the generation of hydroelectric power itself is considered an abiotic flow from geophysical sources.

6.132 Flows related to residuals from economic activity. There is a range of residuals that are released through economic activity including emissions to air, soil and water and the generation of solid waste. In many cases, ecosystems act as sinks or receivers of these residuals. Three cases are considered here:

i. Where residuals are actively remediated, broken down or otherwise processed via ecological processes, for example through air filtration and water purification. In this case, an ecosystem service is measured equivalent to the quantity of residual that is remediated up to the ecological limit or threshold for the given ecosystem asset.

ii. Where residuals are stored in specific areas, such as with landfill or mining overburden. This is considered a case of using the ecosystem's location, i.e., a sink service, and it is treated as a spatial function of the environment. No ecosystem service or abiotic flow should be recorded.

iii. Where residuals are passed through an ecosystem, for example where contaminants from effluent flow into freshwater ecosystems and are subsequently deposited within the sediment or passed on to the marine environment, including in cases where the release of residuals exceeds the ecological limit of the ecosystem to mediate or process the residual. In this case, the storage of pollutants is not considered to reflect an ecosystem contribution but may be considered a sink service. As for case (ii) no ecosystem service or abiotic flow should be recorded unless some remediation occurs (as per case (i)).

6.133 In this third case, increasing concentrations of some residuals will be a significant factor in the decline in condition of ecosystems – e.g., excess nitrogen leading to the eutrophication of lakes and bays. These declines in condition should be recorded in the condition account and may be reflected in decreases in future flows of ecosystem services supplied by the affected ecosystems. However, the presence of residuals in an ecosystem is not, of itself, considered to imply the supply of an ecosystem service.

6.134 In the context of case (i) above, the ability of ecosystems to remediate, dilute and store pollutants (e.g., releases of nitrogen) may be regarded as providing a benefit to the polluter since they do not need to capture and store the residuals themselves or otherwise change

[74] Note that peatlands will also supply other ecosystem services, such as global climate regulation and water purification services.

their practices. Consistent with the advice above, only the remediation role performed by an ecosystem asset is recorded as an ecosystem service for ecosystem accounting purposes. Benefits to the polluter that arise from the dilution or storage of pollutants are considered spatial functions of ecosystems. These flows may be recorded separately.

6.135 The use of the relevant ecosystem services (e.g., water purification) and any spatial functions (e.g., storage of pollutants) may be assigned to the polluter where there is a direct economic benefit to the polluter from this use of the ecosystem, generally a reduction in operating costs. However, in line with case (ii) above, since the total release of the residuals may be greater than the ecosystem can remediate, only a portion of the direct economic benefit should be treated as an ecosystem service. Where the use of ecosystem services is recorded in this way, it is also possible to assign the use of the relevant ecosystem services, e.g., water purification, to other economic units who subsequently use the ecosystem and hence benefit from cleaner water, air and soil, e.g., water supply companies.

6.136 <u>Flows related to the use of the environment for undertaking economic and other activities – spatial functions.</u> These flows relate primarily to the fact that all activities take place in a location. Flows related to the use of environment for these activities are treated as spatial functions within the broader framing of abiotic flows. While ecosystems will, by definition, be present in those locations, there are no ecological processes providing a contribution to those activities that should be recorded as ecosystem services. This implies that the benefits derived from land in supporting buildings, houses, roads, railways and other structures and the associated values related to location are not considered to incorporate ecosystem services. Further, there is no abstraction or extraction from the ecosystem that would require recording abiotic flows. A unique case concerns navigation on rivers where the flow of water supports transportation of people and goods. In this case, there may be a contribution of ecosystem processes, primarily concerning water flow regulation, that should be recorded as a final ecosystem service.

6.137 In many cases, there will be a significant monetary value associated with these uses of the environment, including the value of land under houses. This value should be included in the value of land in the extended balance sheet described in Chapter 11.

6.5 Ecosystem capacity

6.5.1 Introduction

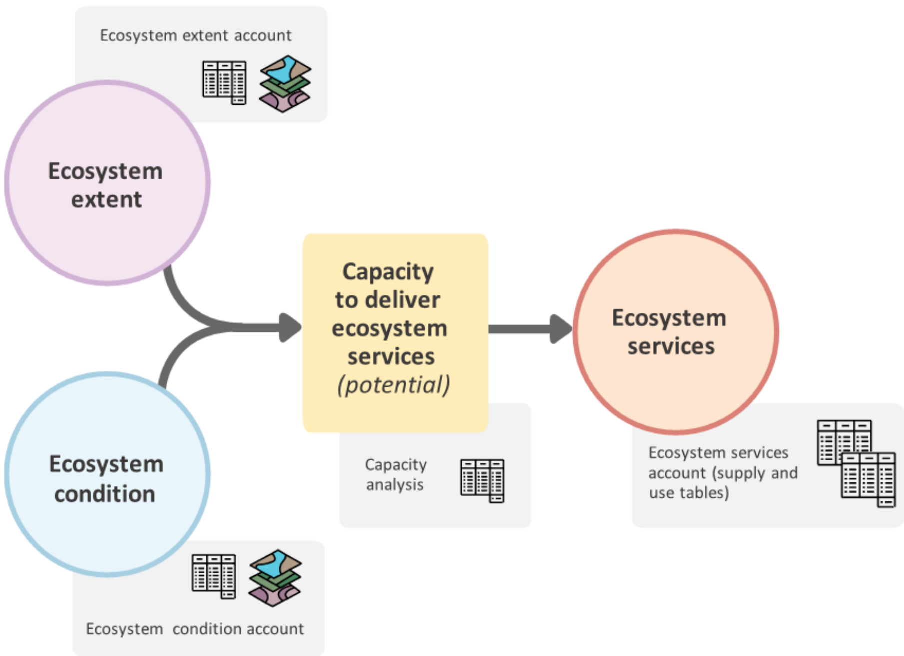
6.138 The general interest in the concept of ecosystem capacity stems from the interest in understanding issues concerning the balance of supply and use of ecosystem services. These issues include the extent to which the current patten of use of an ecosystem is beyond current limits of regeneration and absorption thus affecting the wellbeing of current generations; the extent to which the actual or potential use of ecosystem services reflects the condition of the ecosystem asset; and the relative effects of alternative ecosystem management arrangements on the supply and use of ecosystem services.

6.139 Generally, the underlying concern relates to the potential loss of the quantity and quality of ecosystem assets and the subsequent impacts on the current and future flows of ecosystem services. In some cases, the focus is on local limits with respect to regeneration and overuse, and, in other cases, the limits concern tipping points where there are substantive changes in ecosystem type or breaches of other broader systemic limits.

6.140 In an accounting context, the concept of ecosystem capacity has been most commonly envisaged as embodying a link between measures of ecosystem asset extent and condition on the one hand, and measures of ecosystem services supply and use on the other. Figure 6.1

highlights the nature of the general relationship that is the focus of ecosystem capacity in the SEEA EA. Note that the accounts themselves, in particular the supply and use tables, do not require estimates of ecosystem capacity for their compilation but assessment of capacity can directly support the interpretation and application of accounting entries. Indeed, accounting provides a relatively natural measurement platform for considering the inherent systemic linkages between the current and future patterns of supply and use of ecosystem services and the current and future state of ecosystem assets. This section summarizes the relevant considerations.

Figure 6.1: Relationships between capacity and ecosystem account



Source: Adapted from Maes et al. (2018).

6.5.2 Defining ecosystem capacity for accounting purposes

6.141 In the SEEA EA, ***ecosystem capacity is the ability of an ecosystem to generate an ecosystem service under current ecosystem condition, management and uses, at the highest yield or use level that does not negatively affect the future supply of the same or other ecosystem services from that ecosystem.***

6.142 This definition reflects a variety of contributions to the discussion on ecosystem capacity in an ecosystem accounting, including for example the work of Hein et al. (2016) and La Notte et al. (2019). Given the variety of perspectives on ecosystem capacity the following notes are required to appropriately interpret the intention and meaning of the definition. The need for further research and discussion is also recognised with ecosystem capacity being a specific topic on the SEEA EA research agenda.

6.143 First, the focus of the definition is on capacity of an ecosystem asset to supply a single ecosystem service. It is relatively common for the concept of ecosystem capacity to be framed in a way that speaks to the ability of an ecosystem asset to generate a bundle of ecosystem services. In concept, this would be ideal and would link directly to a range of literature on ecosystems and biodiversity, for example, Mori et al. (2013) concerning the maintenance of ecosystem functions, and option and insurance values of ecosystem assets (see the discussion in section 6.3.3 on the links between ecosystem services and biodiversity).

6.144 A systemic approach to ecosystem capacity can also be related to a discussion on ecosystem characteristics and processes that underpin flows of ecosystem services and to the related idea that an ecosystem needs to supply services to itself to support its functioning. In the SEEA EA, intermediate services are only recorded when they can be linked to final ecosystem services and should not be recorded in the context of solely maintaining ecosystem function. There may be interest in recording various physical flows within and between ecosystems that reflect ecosystem processes but this is not a feature of ecosystem accounting per se (except when they relate to flows of ecosystem services or support the measurement of ecosystem condition).

6.145 While a broader and systemic measurement approach for ecosystem capacity would be ideal, a focus on individual ecosystem services is both more measurable and, while more limited in focus, can be of direct relevance in policy and decision making, for example in setting policy and management targets.

6.146 While there is a focus on a single ecosystem service in this definition, the measurement of capacity will require consideration of the management of the ecosystem asset as a whole. Consequently, for an individual ecosystem, the capacities for each service within a bundle will be connected. Indeed, the concept of ecosystem capacity is most relevant for services that can be overused, e.g., provisioning services. For services, where there is no equivalent concept of overuse (e.g., flood control, or global climate regulation) there is no sustainability threshold, and capacity needs to be considered differently. La Notte et al. (2019) discuss these differences in the concept of ecosystem capacity by type of service.

6.147 Second, this definition can be applied using two main approaches. In one approach, it is assumed that the current ecosystem asset context will not change into the future. This implies that no consideration is given to the potential effects of external drivers (e.g., population growth or climate change) on the ecological limits of an ecosystem with respect to a specific service or on the use of that service. This measurement approach is likely more viable, at least in the short term.

6.148 In an alternative approach, assumptions are made about future changes in the ecosystem asset itself and/or in the expected patterns of ecosystem service use. Also, relevant here are assumptions regarding expected interactions (trade-offs and/or synergies) within the ecosystem in the supply of different ecosystem services – e.g., between timber provisioning services and air filtration services. Making different assumptions about future changes and interactions will alter the measures of the appropriate ecological limits and hence will affect the measurement of capacity. Ideally, these types of considerations would be applied in the monetary valuation of ecosystem assets using an NPV formulation as described in Chapter 10.

6.149 Other observations on the application of this definition are that:

- In physical terms, the measure of capacity for an individual ecosystem service should be expressed in the same quantification/measurement units as the actual flow of the ecosystem service. Thus, capacity would mostly commonly be expressed in terms of a rate per year. When considering measures over multiple ecosystem assets (e.g., for a single ecosystem type), it may also be relevant to present measures in terms of rates per spatial unit (e.g., hectares, volumes) noting these rates will not be constant across an ecosystem asset or ecosystem type.

- Under the first approach, it will be appropriate to account for longer-term cycles of management or disturbance. Thus, for example, rotational harvesting of timber over long management cycles (40-100 years) should be taken into account. Longer-term effects of patterns of disturbance, like fire and flood, and ecosystems' adaptation to these disturbances, are also relevant considerations. Under the second approach, expectations on potential changes in these longer-term cycles would be taken into consideration.

- If the ecosystem service is used at current capacity and there is no use beyond the appropriate limit, the condition of the ecosystem asset should remain stable compared to its current level, all else being equal. Since relevant limits can change over time (e.g., due to climate change) measures of capacity should be regularly reassessed.
- In monetary terms, capacity can be related to the net present value (NPV) of ecosystem service flows at their sustainability thresholds, i.e., using the sustainable ecosystem service flow, as determined by the relevant regeneration and absorption rates. These capacity-based values can be compared to the net present value of ecosystem services based on the actual expected flows. An example showing the difference between sustainable and actual flows and their implications is provided in La Notte et al. (2017).

6.150 In applying the definition above, no measure of capacity is recorded for ecosystem services that might potentially be supplied but are not within the current bundle of ecosystem services from an ecosystem asset. However, the same framework may be applied to estimate an ecosystem's *potential supply* which concerns an ecosystem's ability to generate an ecosystem service without the constraint of considering current patterns of use but still requiring that the condition of the ecosystem is unaffected. Another variant, following Hein et al. (2016), is *ecosystem capability*, which concerns an ecosystem's ability to generate an ecosystem service under current conditions and type of use but irrespective of the potential impacts of increasing the supply of that service on the supply of other ecosystem services. Data from the ecosystem accounts will likely be relevant in the derivation of these complementary measures noting the different assumptions that will be required in their measurement.[75]

6.151 In terms of general interpretation, because of the link between measures of capacity and potential supply and the maintenance of ecosystem condition, a comparison can be made between the actual flow of ecosystem services recorded in the ecosystem accounts and the flow of that service at its capacity or threshold level which can be regarded as a sustainable flow. Measures of ecosystem capability do not have this interpretation, i.e., a flow related to ecosystem capability may not be sustainable.

6.152 While there is an apparent logical connection between increases in ecosystem condition and increases in capacity, this may not apply for all ecosystem services. For example, primarily for provisioning services, the capacity may be higher at levels of condition that are somewhat below the reference condition. Thus, while as a general observation, higher levels of condition would be associated with higher measures of capacity, this will not hold in all circumstances. Further, the precise nature of the relationship between falls in condition and falls in capacity may be unclear, at least in the short term.

6.5.3 Defining ecosystem capacity with respect to specific types of ecosystem services

6.153 The description and measurement of ecosystem capacity will vary across different types of ecosystem services (La Notte et al., 2019). For provisioning services, capacity will relate to the rates of regeneration that are possible under current conditions.

6.154 For regulating and maintenance services, the underlying ecological assumption is that there are limits or thresholds to the supply of these services. These limits may present themselves in different ways. For services where there is remediation of pollutants, such as water

[75] Additional references on this topic include Burkhard et al. (2014) and Villamagna et al. (2013).

purification, there will be a limit as to the quantity of pollutant that can be remediated and processed. In this case ecosystem capacity will reflect that limit. For services which may be described as providing "buffer" services, such as water flow regulation and flood control services, there will be associated maximum rates of infiltration and related ecological boundaries that may be used to determine ecosystem capacity.

6.155 For cultural services, the issue of capacity arises only in the context of in situ use of the ecosystem. In these cases, capacity measures will relate to the maximum number of people able to visit or enjoy a particular site without loss of ecosystem condition.

6.156 In practice, it may not be necessary to measure ecosystem capacity for all ecosystem services. An initial focus could be on those ecosystem services whose overuse is most likely to have negative effects on ecosystem condition. From a risk management perspective, this might be appropriate and it certainly provides a basis for prioritization of ecosystem services for measurement.

6.157 Further on the issue of measurement focus, the concept of ecosystem capacity will be less relevant in cases where there is no, or very limited, use of an ecosystem service, for example air filtration services by forests in northern Canada. Measurement of ecosystem capacity in these contexts may suggest a level of available capacity which is not consistent with current and expected patterns of use.

6.158 In this context, note that the reference in the definition to current management and uses implies that the measurement of capacity must take into account restrictions on access or use of ecosystems. For example, if a forest has been designated as a protected area and logging is not possible, then the capacity to supply biomass provisioning services will be zero. Similarly, a beach to which no recreational access is allowed has zero capacity to supply recreation-related services.

6.159 It is expected that through the development of ecosystem accounting generally and compilation of the various ecosystem accounts, significant further advances can be made in accounting for ecosystem capacity. This will include both measurement advances, such as determining best practices in setting thresholds for individual services and moving beyond individual ecosystem services to consider bundles of services from an ecosystem; and conceptual developments, such as integrating the concept of ecosystem capacity into the definition of ecosystem enhancement and degradation.

Annex 6.1: Initial logic chains for selected ecosystem services

Ecosystem Service	Common ecosystem type/s	Factors determining supply		Factors determining use	Potential physical metric(s) for the ecosystem service	Benefits	Main users and beneficiaries
		Ecological	Societal				
Crop provisioning services	Cropland	Soil fertility, especially chemical state (e.g., soil organic carbon, nutrients); climate; water supply; pollination; genetics	Farm management at different stages of production process; Harvesting practices; Air pollution affecting soil quality	Demand for biomass (e.g., for food)	Gross tonnes of cultivated plants e.g., wheat (proxy measure)	Crop products – e.g., harvested wheat (SNA benefit)	Agricultural producers, including household and subsistence production
Grazed biomass provisioning services	Pastures	Soil fertility; climate; water supply; genetics	Farm management at different stages of production process	Demand for biomass (e.g., as food for livestock); farming practices	Gross tonnes of grazed biomass	Livestock and livestock products (e.g., meat, milk, eggs, wool) (SNA benefits)	Agricultural producers, including household and subsistence production; households
Wood provisioning services	Forests, woodland	Soil fertility; climate; water supply; timber stock biomass and composition; genetics	Forest management and harvesting practices	Demand for timber	Gross tonnes of wood (timber) biomass harvested	Harvested timber (SNA benefit)	Forestry producers, including households
Wild fish and other natural aquatic biomass provisioning services	Mainly marine, freshwater	Stock biomass and composition; especially Structural State (e.g., trophic composition number, ratio between fishing mortality and fishing at maximum sustainable yield); Chemical State (e.g., temperature, pH, eutrophication, salinity)	Stock management practices, harvesting practice	Demand for aquatic biomass	Gross tonnes of aquatic products harvested	Harvested aquatic products (SNA benefit)	Fishing industry, including direct household consumption; recreational fishing
Wild animals, plants and other biomass provisioning services (excludes aquatic and wood products)	Many ecosystem types	Ecosystem extent and condition; biomass stock; climate	Ecosystem management	Demand for ‘natural’ products	Tonnes of biomass harvested	Harvested products (SNA or non-SNA benefit)	Households, businesses
Water supply	Freshwater, marine, groundwater ecosystems	Quantity and quality of water stocks	Catchment management practices	Demand for water by type of quality	Cubic metres of water, by type of quality	Consumptive use by the economy and society (SNA benefit)	Water supply utilities, direct household consumption; other

Ecosystem Service	Common ecosystem type/s	Factors determining supply		Factors determining use	Potential physical metric(s) for the ecosystem service	Benefits	Main users and beneficiaries
		Ecological	Societal				
							users of water (e.g., farmers)
Global climate regulation services	Primarily forest, woodland and shrubland ecosystems, also grasslands and cropland, wetlands, marine ecosystems	Ecosystem type and condition, especially Structural State (e.g., tree cover density and forest age); atmospheric carbon concentrations	Ecosystem management; GHG emissions	Vulnerability to climate change (exposure, sensitivity and adaptive capacity)	Tonnes of carbon and other greenhouse gases retained (sequestered & stored)	Reduced concentrations of GHG in the atmosphere leading to less climate change and fewer adverse effects (non-SNA benefit)	Collectively consumed by government on behalf of society (individuals, households and businesses globally)
Local (micro and meso) climate regulation services	Mainly urban ecosystems(for people); pastures (for livestock)	Ambient atmospheric conditions; type and quantity of vegetation; presence of water bodies	Ecosystem management; urban planning practices	Location of people and animals in relation to vegetation and blue spaces	Number of households with air temperature reduced by more than 5˚ C on hot days	Improved living conditions and economic production (non-SNA benefit)	Households, businesses
Air filtration services	Mainly forest and woodland	Type and condition of vegetation, especially functional state (e.g., Leaf Area Index) and chemical state (e.g., ambient pollutant concentration)	Ecosystem management; location type and volume of released air pollutants	Behavioural responses; and location and number of people and buildings affected by pollution	Tonnes of pollutants absorbed by type of pollutant (e.g., PM10; PM2.5)	Reduced concentrations of air pollutants providing improved health outcomes and reduced damage to buildings (non-SNA benefit)	Households; businesses (through reduced damage to buildings)
Soil and sediment retention services - **Soil erosion control services** - **Landslide mitigation services**	Many ecosystem types	Topology; Geology and soil type; Type and condition of vegetation, especially Structural state (e.g., vegetated river banks); rainfall patterns	Ecosystem management	Demand for agricultural and wood biomass; location of managed water bodies at risk from sedimentation; Location of people and buildings at risk from landslides	Tonnes of soil retained; number of properties with reduced risk of landslide	Soil stability: reduced sedimentation downstream (non-SNA benefit); reduced risk of landslide (non-SNA benefit)	Households and businesses

Ecosystem Service	Common ecosystem type/s	Factors determining supply		Factors determining use	Potential physical metric(s) for the ecosystem service	Benefits	Main users and beneficiaries
		Ecological	Societal				
Solid waste remediation	Many ecosystem types, mainly cropland	Condition of soils, especially micro-organisms	Ecosystem management	Type and quantity of solid waste released	Tonnes of solid waste remediated	Reduced impact of alternative methods of disposal (non-SNA benefit)	Businesses including household and subsistence production
Water purification services	Many ecosystems, primarily freshwater and marine ecosystems and associated vegetation	Ecosystem type and condition; Composition of micro-organisms and algae; chemical state (e.g., nitrogen and phosphorus concentrations)	Location type and volume of released water pollutants	Demand for cleaner water for different uses	Tonnes of pollutants remediated by type of pollutant (nutrients and other pollutants)	Reduced concentrations of water pollutants providing improved health outcomes and/or reduced water treatment costs (non-SNA benefit)	Households and businesses
Water flow regulation services **– baseline flow maintenance** **– peak flow mitigation**	Terestrial and freshwater ecosystems within riparian and upstream zones	Extent and condition of vegetation and soils (e.g., water infiltration rate); rainfall patterns	Ecosystem management	Demand for water supply at different times of the year (baseline flow maintenance); extent of existing produced assets and location of properties (peak flow mitigation)	Capacity of reservoirs or alternative forms of storage (cubic metres) otherwise needed to provide same service	Reduced need for other forms of water storage for human use or for flood defence (non-SNA benefit)	Households and businesses
Coastal protection services	Shoreline systems	Extent and condition of vegetation; and of other features of coastal margins (e.g., coral reefs, sand banks and dunes); ambient climate factors	Ecosystem management	Extent of existing produced assets (e.g., flood barriers, dykes); location of properties	Number of properties in a lower risk category	Reduced impact or frequency of flood events (non-SNA benefit)	Property owners and residents – households, business, government
River flood mitigation services	Terrestrial and freshwater ecosystems within riparian zones	Extent and condition of riparian vegetation; ambient climate factors	Ecosystem management	Extent of existing produced assets (e.g., flood barriers, dykes); location of properties	Number of people and buildings in a lower risk category	Reduced impact of flood events (non-SNA benefit)	Property owners and residents – households, , businesses, government
Pollination services	Many ecosystem types, mainly near cropland areas, but also urban gardens	Abundance and location of wild pollinators	Ecosystem management	Location of crops benefiting from wild pollination	Area of crops pollinated, by type of crop	Reduced need for alternative forms of pollination, including paid pollinator services (SNA benefit)	Cropland ecosystems, ultimately agricultural production including households and

Ecosystem Service	Common ecosystem type/s	Factors determining supply		Factors determining use	Potential physical metric(s) for the ecosystem service	Benefits	Main users and beneficiaries
		Ecological	Societal				
							subsistence production; households
Nursery population and habitat maintenance services	All ecosystems	Species-level diversity, abundance; condition of ecological communities	Ecosystem management	Demand for biomass which depends upon nursery and habitat services	Size of biomass stocks dependent upon nursery and habitat services	Continuing supply of ecosystem services (non-SNA benefit)	All ecosystems, ultimately all sectors of society
Recreation-related services	Many ecosystem types	Extent and condition; presence of iconic landmarks or species; structural state and landscape/seascape characteristics (e.g., % urban green space, distance to open green space)	Ecosystem management including facilities to support access	Accessibility of recreation sites; location of users; demand for outdoor recreation	Number and length (hours) of visits	Physical and mental health; enjoyment (non-SNA benefit)	Households; tourism and outdoor leisure service sectors
Visual amenity services	Many ecosystem types	Landscape setting and condition (e.g., structural state and landscape/seascape characteristics)	Landscape management	Location and design of residential and office buildings; demand for housing in green/blue areas	Number of properties with views of natural landscapes/located near green/blue areas	Higher values of dwellings (SNA benefit); mental health, enjoyment (non-SNA benefit)	Households
Education, scientific and research services	Many ecosystem types	Extent and condition; presence of iconic landmarks or species; structural state and landscape/seascape characteristics	Access to ecological sites of interest	Education policies, research priorities and funding	Number of visits for educational, scientific and research purposes	Intellectual development, advancement of knowledge and understanding (non-SNA benefit)	Educational and research organisations

7 Accounting for ecosystem services in physical terms

7.1 Introduction

7.1 Accounting for ecosystem services in physical terms aims to record, in an accounting structure, the flows of ecosystem services over an accounting period in physical units such as cubic metres and tonnes. Physical quantification commonly focuses on measurement of ecosystem structures, processes and functions; i.e., the supply side of ecosystem service flows but quantification of ecosystem contributions can also take place through a focus on the use of ecosystem services, for example the number of visits to a national park. A key focus in accounting for ecosystem services is reconciling the supply and the use of ecosystem services across multiple ecosystem assets and multiple users.

7.2 Flows of the ecosystem services in the reference list (see Chapter 6) can be measured in physical, i.e., quantitative, terms. Different ecosystem types will supply different bundles of ecosystem services to different users. The aim in ecosystem accounting is to provide as comprehensive coverage as practical of the supply and use of different ecosystem services within an ecosystem accounting area. The choices about which ecosystem services to include in a set of ecosystem accounts will depend in part on the data and resources available for the compilation of estimates.

7.3 Ecosystem service flow accounts in physical terms that record the supply and use of ecosystem services may be compiled for a range of reasons and purposes. These include recording and monitoring the different bundles of ecosystem services supplied by different ecosystem types, identifying the users of the services, and assessing how these patterns of supply and use are changing over time. This information can underpin analysis of the significance of particular ecosystems as ecosystem service suppliers, support analysis of trade-offs between different ecosystem services as part of spatial planning and land management, and provide information to support delineation of areas for specific land uses, including for conservation and environmental protection. While some of these applications will be appropriate at larger, national scales, in many cases the use of spatial data on ecosystem services supply and use will open up considerable analytical opportunities at finer scales. Much work on accounting for ecosystem services has been conducted using spatial data and for some services this is the likely entry point for measurement, particularly for regulating and maintenance services.

7.4 The information on ecosystem services in physical terms can also be used to demonstrate the nature of the connection to the SNA production boundary which, in turn, can support engagement and discussion of the wider, non-private, benefits of ecosystems beyond ecosystem contributions to marketed goods and services. The data in physical terms will also underpin monetary valuation of ecosystem services (see Chapter 9).

7.2 Ecosystem services flow accounts in physical terms

7.2.1 Overall structure of the ecosystem services flow accounts

7.5 The structure of the ecosystem services flow accounts in physical terms is displayed in Table 7.1a and 7.1b. The structures of these tables follow those of the supply and use tables (SUT) described in the SNA and the SEEA Central Framework. In an ecosystem accounting context, ***supply and use tables are accounting tables structured to record flows of final ecosystem***

services between economic units and ecosystems and flows of intermediate services among ecosystems. Entries can be made in physical and monetary terms.

7.6 The list of ecosystem services in Table 7.1a and 7.1b reflects the reference list of selected ecosystem services in Chapter 6. Conceptually, a supply and use table in physical terms would only contain entries recorded in the same measurement unit – e.g., energy supply and use tables are recorded in terms of joules and water supply and use tables in terms of cubic metres. Where this is done, it is possible to aggregate across the rows of the tables. In the presentation here, a selection of ecosystem services is included, each recorded using their own measurement units. Consequently, it is not possible to aggregate down the rows in the tables to obtain meaningful aggregates. While individual supply and use tables for each ecosystem service could be presented, the conceptual considerations for the structure of the tables and associated accounting entries would be identical to those discussed here.

7.7 A key principle of the supply and use table structure is that the supply of ecosystem services is equal to the use of those services during an accounting period. This is the application of the supply and use identity (SEEA Central Framework, para. 3.35). Thus, for example, both the supply and the use of air filtration services should be recorded using the same measurement unit, for example, tonnes of PM2.5 absorbed by vegetation.

7.8 Table 7.1a presents the supply table. It records the flows of different ecosystem services supplied by different ecosystem types. The total supply recorded should include both final ecosystem services and intermediate services. Table 7.1b presents the use table. It records the use of different ecosystem services by economic units (final ecosystem services) and by other ecosystem assets (intermediate services). For each ecosystem service, the total supply recorded in Table 7.1a must equal the total use recorded in Table 7.1b. Details about the recording principles and specific treatments are described in the following sections.

7.9 The flows for each ecosystem service are recorded using a unit of measure that is appropriate for that ecosystem service. The column titled "Units of measure" provides an example of the type of unit that may be appropriate for each type of service. Common units of measure include tonnes, cubic metres and number of visits. In practice, the unit of measure that is applied will depend on the data available and the measurement method that is used. There are no prescribed measurement units in the SEEA EA but relevant technical guidance is being developed in the *Guidelines on Biophysical Modelling for Ecosystem Accounting* (UNSD, n.d.-a, forthcoming).

7.10 The units used to measure the supply of the service must also be used to measure the use of the service. This applies also where an ecosystem service is supplied by multiple ecosystem types and/or used by multiple economic units. Thus, across a single row (i.e., for a single ecosystem service), the same unit of measure should be applied. This enables a total supply and total use to be estimated for each individual ecosystem service. However, as noted above, since each ecosystem service will be measured using different units, it is not possible to aggregate to provide an estimate of the total supply or use of multiple services in physical terms for an ecosystem type or economic unit.

7.11 Each ecosystem service is recorded as being supplied by an ecosystem type. For the purposes of demonstrating the design of a supply table, Table 7.1a shows selected ecosystem types based on selected classes from the Ecosystem Functional Group (EFG) level of the IUCN GET (see Chapter 3 for details). The set of classes shown is not exhaustive for that level. In practice, it is expected that countries will apply a national or regionally applicable classification of ecosystem types. This may show additional detail compared to the EFG level.

Table 7.1a: Ecosystem services supply and use account in physical terms – supply table

					Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																		Total Supply resident ecosystem assets	Supply from non-resident ecosystem assets - Imports	Total Supply ecosystem services	TOTAL SUPPLY
					Terrestrial												Freshwater			Marine						
					T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				…		T7		F1	…	FM1	M1	…	MFT1				
					Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	…	Temperate pyric sclerophyll forests and woodlands	…	…	…	Derivied semi-natural pastures and old fields	Permanent upland streams	…	Intermittently closed and open lakes and lagoons	Seagrass meadows	…	Coastal saltmarshes and reedbeds				
SUPPLY			UNITS OF MEASURE		T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	…	T2.6	…	…	…	T7.5	F1.1	…	FM1.3	M1.1	…	MFT1.3				
Selected ecosystem services (reference list)																										
Provisioning services																										
	Biomass provisioning	Crop provisioning																								
		Grazed biomass provisioning																								
		Livestock provisioning services																								
		Aquaculture provisioning services																								
		Wood provisioning services																								
		Wild fish and other natural aquatic biomass provisioning services																								
		Wild animals, plants and other biomass provisioning services																								
	Genetic material services																									
	Water supply																									
	Other provisioning services																									
Regulating and maintenance services																										
	Global climate regulation services																									
	Rainfall pattern regulation services																									
	Local (micro and meso) climate regulation services																									
	Air filtration services																									
	Soil quality regulation services																									
	Soil and sediment retention services																									
	Solid waste remediation services																									
	Water purification services																									
	Water flow regulation services																									
	Flood control services																									
	Storm mitigation services																									
	Noise attentuation services																									
	Pollination services																									
	Biological control services																									
	Nursery population & habitat maintenance services																									
	Other regulating and maintenance services																									
Cultural services																										
	Recreation-related services																									
	Visual amenity services																									
	Education, scientific and research services																									
	Spiritual, artistic and symbolic services																									
	Other cultural services																									

Table 7.1b: Ecosystem services supply and use account in physical terms – use table

				Selected economic units														
				Selected industries														
USE			UNITS OF MEASURE	Agriculture	Forestry	Fisheries	Mining and quarrying	Manufacturing	Electricity, gas, steam and air conditioning supply	Water supply; sewerage, waste management and remediation activities	Services	Other industries	Total Industry	Government consumption	Household consumption	Total use by resident economic units	Exports - final ecosystem services	Total Use by economic units
Selected ecosystem services (reference list)																		
Provisioning services																		
	Biomass provisioning	Crop provisioning																
		Grazed biomass provisioning																
		Livestock provisioning services																
		Aquaculture provisioning services																
		Wood provisioning services																
		Wild fish and other natural aquatic biomass provisioning services																
		Wild animals, plants and other biomass provisioning services																
	Genetic material services																	
	Water supply																	
	Other provisioning services																	
Regulating and maintenance services																		
	Global climate regulation services																	
	Rainfall pattern regulation services																	
	Local (micro and meso) climate regulation services																	
	Air filtration services																	
	Soil quality regulation services																	
	Soil and sediment retention services																	
	Solid waste remediation services																	
	Water purification services																	
	Water flow regulation services																	
	Flood control services																	
	Storm mitigation services																	
	Noise attenuation services																	
	Pollination services																	
	Biological control services																	
	Nursery population & habitat maintenance services																	
	Other regulating and maintenance services																	
Cultural services																		
	Recreation-related services																	
	Visual amenity services																	
	Education, scientific and research services																	
	Spiritual, artistic and symbolic services																	
	Other cultural services																	

			Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																					
			Terrestrial												Freshwater			Marine						
			T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1				
			Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	...	Temperate pyric sclerophyll forests and woodlands	...	...	...	Derived semi-natural pastures and old fields	Permanent upland streams	...	Intermittently closed and open lakes and lagoons	Seagrass meadows	...	Coastal saltmarshes and reedbeds	Total use by resident ecosystem assets	Exports - intermediate services	Total Use by ecosystem assets	TOTAL USE
USE			T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3				
Selected ecosystem services (reference list)																								
Provisioning services																								
	Biomass provisioning	Crop provisioning																						
		Grazed biomass provisioning																						
		Livestock provisioning services																						
		Aquaculture provisioning services																						
		Wood provisioning services																						
		Wild fish and other natural aquatic biomass provisioning services																						
		Wild animals, plants and other biomass provisioning services																						
	Genetic material services																							
	Water supply																							
	Other provisioning services																							
Regulating and maintenance services																								
	Global climate regulation services																							
	Rainfall pattern regulation services																							
	Local (micro and meso) climate regulation services																							
	Air filtration services																							
	Soil quality regulation services																							
	Soil and sediment retention services																							
	Solid waste remediation services																							
	Water purification services																							
	Water flow regulation services																							
	Flood control services																							
	Storm mitigation services																							
	Noise attenuation services																							
	Pollination services																							
	Biological control services																							
	Nursery population & habitat maintenance services																							
	Other regulating and maintenance services																							
Cultural services																								
	Recreation-related services																							
	Visual amenity services																							
	Education, scientific and research services																							
	Spiritual, artistic and symbolic services																							
	Other cultural services																							

7.12 While many ecosystem services are supplied by an individual ecosystem type in a single location, some ecosystem services are supplied by a combination of ecosystem types (e.g., flood mitigation services supplied by a combination of ecosystems within a riparian zone). In these situations, an allocation of the total supply to the relevant ecosystem assets and ecosystem types is required. Section 7.3.1 discusses the spatial allocation of ecosystem services.

7.13 Table 7.1b presented the use table. It records the use of ecosystem services by economic units – final ecosystem services - and by ecosystem types – intermediate services. Economic units are classified following the general structure of the SNA. Seven industry classes are shown in Table 7.1b. Selected industry classes may be more detailed to allow for national contexts. It is recommended that the structure used aligns with the International Standard Industrial Classification (ISIC). The columns for Government and Households reflect their consumption of ecosystem services while the column for exports reflects the use of ecosystem services by non-residents (e.g., recreation related services used by international visitors). For analytical purposes, the column for households may be broken down to distinguish different types of households (e.g., by income quintile or rural and urban households) to provide further detail on the distribution of use of ecosystem services.

7.14 In the use table, the ecosystem types are shown for the four realms of the IUCN GET that are within scope of ecosystem accounting. This higher-level presentation is used for demonstration purposes only, and more detailed classes can be used. The recording of intermediate services by ecosystem type is not applicable for provisioning or cultural services; i.e., all of these types of services are final ecosystem services and hence cannot be used by an ecosystem type. Where there are intermediate services that appear provisioning in nature, e.g., the connections between trophic layers of fish, or the drinking of water by animals, these should be recorded as part of nursery population and habitat maintenance services.

7.15 In general, the measurement scope of a supply and use account will be established on the basis of the ecosystem services supplied by all ecosystem types within an EAA. To ensure a balance in the recording of supply and use, this implies the need to record the use of ecosystem services by non-resident economic units, i.e., economic units who have a centre of economic interest outside of the EAA. This may arise, for example, in the case of cultural services being supplied to visitors living outside the EAA. A column at the centre of the use table allows these flows to be recorded as exports of ecosystem services. Note that the total use of final ecosystem services supplied by ecosystems within an EAA will include exports of final ecosystem services. Imports of ecosystem services supplied by ecosystem assets outside the EAA may also be recorded. Entries are made in the final column of the supply table. Section 7.2.6 provides additional discussion on the recording of imports and exports of ecosystem services.

7.16 A single supply and use table is compiled for one accounting period, usually one year. That is, the entries for supply and use show the total flows of each ecosystem service for that time period. Ideally, a time series of supply and use tables would be compiled to enable analysis of changes in the patterns of supply and use over time but it may be more practical initially to compile tables once every three or five years to allow for the development of methods and experience. Where a time series of supply and use tables is compiled, different presentations and arrangements of the components may be required to support showing time as one dimension.

7.17 There may also be considerable interest in the presentation of data on the supply and use of ecosystem services in the form of maps. Overlaying maps for different ecosystem services can provide a ready source of information on places that might be considered ecosystem services "hot spots." It is common for estimates of the supply and use of ecosystem services to be compiled using detailed spatial data such that the flows of ecosystem services can be attributed to specific locations and hence to associated ecosystem types. Where this compilation approach is used, the entries in the supply and use table which shows flows by ecosystem type, will be an aggregation of data from finer scales and thus the maps and tables are complementary outputs of the same underlying data.

7.18 Where more aggregate, economy wide methods are used, for example where ecosystem service flows are based on aggregate visits to national parks or total volumes of timber harvested for a country, the attribution to ecosystem type may be more generic or stylized and there may be no accompanying mapped outputs.

7.19 In concept, where compilation of ecosystem services is undertaken using fine level spatial data, it would be possible to present information on the supply and use of ecosystem services for each individual ecosystem asset. However, in practice, there is no requirement for reporting at this level of detail, especially for accounts covering a national scale or large areas within a country. Thus, the supply and use tables shown in Table 7.1a and 7.1b focus on recording at the level of ecosystem types, regardless of their location.

7.2.2 Applying general supply and use principles in ecosystem accounting

7.20 In concept, ecosystem accounting considers that each ecosystem supplies, or contributes to the supply of, a set or bundle of ecosystem services. The following discussion retains a focus on explaining the principles and treatments of accounting for ecosystem services at the level of individual ecosystem assets. It is recognised that in practice, compilation may commonly be undertaken for ecosystem types and, as noted in the previous sub-section, the presentation of data in a supply and use table is likely to concern ecosystem types.

7.21 As described in Chapter 6, ecosystem services are defined as contributions to benefits and encompass a wide range of services provided to economic units (households, businesses and governments) and to other ecosystem assets. The distinction between services and benefits is meaningful, because:

- It facilitates distinguishing between final ecosystem services and flows of products (SNA benefits) currently recorded in the SNA.
- It recognises the role of human inputs in the production process and that the contribution of ecosystem services to benefits may change over time (for example, due to changes in the methods of production).
- It identifies the appropriate target for monetary valuation, since the value of final ecosystem services will represent only a portion of the overall monetary value of the corresponding benefits.

7.22 These features also allow clear articulation and attribution of flows between ecosystem assets and economic units that are represented in accounting terms as supply-use pairs, i.e., transactions.

7.23 As described above, the ecosystem services flow account is structured to record the flows of ecosystem services supplied by ecosystem types and used by economic units during an accounting period. There is no accumulation of ecosystem services such that supply over an accounting period might be matched with an increase in accumulated ecosystem services available for use in future accounting periods. While measurement of the potential or sustainable level of supply that could be delivered by an ecosystem asset is highly relevant, this is not the focus of recording in the supply and use accounts. Section 6.5 provides a discussion on the related concept of ecosystem capacity.

7.24 Recording supply as equal to use means that, from an accounting perspective, ecosystem services are revealed transactions or exchanges. Since, in concept, each recorded exchange is observable, it follows that each ecosystem service is separable even though the processes by which different ecosystem services are supplied are connected to each other.

7.25 In addition to requiring matched supply and use entries, the following key features of supply and use accounting are applied.

- Supply is attributed to an ecosystem type. Where an ecosystem service is jointly supplied by a combination of ecosystems, then it is assumed that, if required, the supply can be allocated to individual assets using spatial allocation methods or measurement conventions. This topic is discussed further in section 7.3.
- Use of final ecosystem services is attributed to a resident economic units (business, government, households) or non-resident economic units (exports).
- Use of intermediate services is attributed to an ecosystem type.
- For any single transaction of an ecosystem service (i.e., where there is a supply-use pair) the magnitude of the flow will be the same for both supply and use in terms of quantity and monetary value.
- Where there are multiple transactions of a single ecosystem service (i.e., there are multiple supply-use pairs), the supply and use table allows recording supply from multiple ecosystem types and use by multiple users. Where a total flow is estimated pertaining to multiple ecosystem types or multiple users, attribution to relevant ecosystem types and users will be required to best reflect the underlying transactions.

7.26 Using these principles allows the data recorded in the supply and use table to support the monetary valuation of ecosystem services (described in Chapter 9) and to be considered in an aligned manner with the economic data recorded in the SNA supply and use table (see 2008 SNA, Chapter 14).

7.27 In some cases, the physical flows recorded in the ecosystem services flow account will be the same as those recorded in the physical supply and use tables and asset accounts in the SEEA Central Framework (Chapters 3 & 5). For example, the flow of timber resources harvested from non-cultivated forests will be the same in terms of the reduction in the stock of timber resources in the asset account and the flow of biomass provisioning services in the ecosystem services flow account. This does not represent double counting since each table is designed for a distinct purpose and the flow happens to be relevant in both cases. Compilers are encouraged to cross-check among the various tables to ensure that users are presented with a coherent set of data and to optimise the use of source data and the alignment of methods.

7.2.3 Ecosystem services and benefits

7.28 Where the flow of ecosystem services is an input to the production of an SNA benefit, a supply and use pair is recorded for the ecosystem service in the ecosystem service supply and use account and a separate supply and use pair is recorded in the standard, economic supply and use accounts for the transaction in the associated economic good or service, i.e., the SNA benefit.

7.29 For example, the supply of biomass provisioning services for rice from a cropland is recorded as a use by the farmer of that ecosystem service in the ecosystem service supply and use account. Entries for these flows are shown in Table 7.2.

Table 7.2: Basic Ecosystem services physical supply and use table #1

	Units of measure	Economic units (selected)			Ecosystem assets (selected types)		
		Agri.	Gov.	Households	Forest	Cropland	Grassland
SUPPLY							
ES #1: Biomass provisioning services (rice)	Tonnes					100	
USE							
ES #1: Biomass provisioning services (rice)	Tonnes	100					

Note: Grey cells indicate not applicable. "ES" denotes final ecosystem services.

7.30 Separately, supply-use pairs for the harvested rice and other processed goods will be recorded in the economic supply and use tables reflecting a series of transactions between a farmer, manufacturers and households. This recording allows the supply and use of ecosystem services to be connected to entries for the supply and use of goods and services currently recorded in standard economic supply and use tables, recognizing that the entries in these tables are in monetary terms. The compilation of extended supply and use tables building on the ecosystem services flow accounts in monetary terms is described in Chapter 11.

7.31 Where the flow of ecosystem services is an input to the production of a non-SNA benefit, for example the contribution of air filtration services to cleaner air, a supply and use pair is recorded for the ecosystem service in the supply and use table by adding a row. Entries showing flows for both air filtration and biomass provisioning services are shown in Table 7.3.

Table 7.3: Basic Ecosystem services physical supply and use table #2

	Units of measure	Economic units (selected)			Ecosystem assets (selected types)		
		Agri.	Gov.	Households	Forest	Cropland	Grassland
SUPPLY							
ES #1: Biomass provisioning services (rice)	Tonnes					100	
ES #2: Air filtration services (PM2.5)	Tonnes				50		
USE							
ES #1: Biomass provisioning services (rice)	Tonnes	100					
ES #2: Air filtration services (PM2.5)	Tonnes			50			

Note: Grey cells indicate not applicable.

7.32 For many ecosystem services that contribute to non-SNA benefits, the use of the ecosystem service is attributed to the receiver of the non-SNA benefit. In some cases, this is very direct, e.g., for recreation-related services. However, where the ecosystem service contributes to a non-SNA benefit that is considered "collective", the use of the ecosystem service is attributed to the highest level of general government in the EAA which is considered to use the service on behalf of society as a whole. Following the SNA, "*a collective consumption service is a service provided simultaneously to all members of the community or to all members of a particular section of the community, such as all households living in a particular region. … Collective services are the "public goods" of economic theory*." (2008 SNA, para. 9.4). Collective services will thus be both non-rival and non-excludable. The primary example of such an ecosystem service is global climate regulation, the benefits of which are obtained by all members of the community.

7.33 There are also cases where a single ecosystem service is used by a number of economic units – e.g., in the case of flood mitigation. In this context, the service will have some characteristics of public goods although specific beneficiaries can be identified. Ideally, the service should be recorded as received by multiple economic units in the use table making the distinction, for example, between use by households and use by businesses. However, making this use allocation may be difficult in practice and, in this case, it is recommended to allocate the use of the service to general government on behalf of all users.

7.2.4 Recording intermediate services

7.34 Where there is a sequence of intermediate services and final ecosystem services, recording the supply and use of each service ensures that the appropriate net effect is shown. Using an example involving the ecosystem services of pollination and biomass provisioning services (in this example melons), the supply and use of pollination services from one ecosystem (natural grassland where the pollinators are assumed to live) to another (cropland where the melons are pollinated) is recorded as a supply and use of an intermediate service. Thus, the supply of the intermediate service of pollination is attributed to the grassland and there is a use of pollination services by the cropland (as an input to its supply of final ecosystem services) and supply of biomass provisioning services. The relevant entries are shown in Table 7.4.

Table 7.4: Basic Ecosystem services physical supply and use table #3

	Units of measure	Economic units (selected)			Ecosystem assets (selected types)		
		Agri.	Gov.	Households	Forest	Cropland	Grassland
SUPPLY							
ES #1: Biomass provisioning services (melons)	Tonnes					80	
ES #2: Air filtration services (PM2.5)	Tonnes				50		
IS: Pollination services	# Visits*						2000
USE							
ES #1: Biomass provisioning services (melons)	Tonnes	80					
ES #2: Air filtration services (PM2.5)	Tonnes			50			
IS: Pollination services	# Visits*					2000	

Notes: Grey cells indicate not applicable. "IS" denotes intermediate services. * The number of pollinator visits is one potential measure of the quantity of pollination services. Other metrics may be used.

7.35 By ensuring that a sequence of supply and use entries are recorded for each type of ecosystem service, the overall contribution of each ecosystem can be determined. Thus, for example, by considering the column for cropland, the output of biomass provisioning services can be seen to require the input of pollination services from grassland ecosystems. Note however that no aggregation across rows should be undertaken given that the entries reflect the use of different measurement units. Further, note that there is no double counting implied through the recording of intermediate services since the user of the intermediate service is different from the user of the associated final ecosystem service.

7.36 In the context of recording physical flows of ecosystem services for cultivated biomass production (see section 6.4.1), this approach to recording intermediate services can be applied irrespective of whether the relevant final ecosystem services are measured using gross biomass harvested as a proxy or using a share of biomass harvested to represent the ecosystem contribution. In both of these approaches, the intermediate service flows can be considered inputs to the final flows. However, where the final ecosystem services are measured using a range of individual ecosystem inputs, such as pollination, then no measure of biomass harvested is recorded and each input is recorded as a final ecosystem service. Note that the supply and use table format is designed to record multiple connections but it is necessary that before the entries are made, the logic of the connections are well understood and reflect a coherent and robust description of the relationship between the ecosystems and human activity in biophysical terms. In the context of cultivated biomass production, this should consider the type of biomass (e.g., crop type), the location and the method of cultivation.

7.2.5 *Recording abiotic flows*

7.37 Chapter 6 identified a range of environmental flows, e.g., concerning the supply of energy, that do not meet the definition of ecosystem services and are considered abiotic flows. These abiotic flows may be relevant in the assessment of the use of specific ecosystems. For example, in the production of solar energy it will be common to install solar panels which will reduce the potential to use the location for the generation of ecosystem services. Thus, recording abiotic flows and attributing their supply to individual locations can help provide a more comprehensive picture on the use of ecosystems.

7.38 Where recording abiotic flows is desired, additional rows may be added to the supply and use table (Table 7.1a & Table 7.1b). Each additional row in the supply table would show the supply of the abiotic flow from the relevant ecosystem type (e.g., electricity generated from wind turbines on cropland). Each additional row in the use table would show the use of that abiotic flow by economic units (e.g., electricity generators). Table 7.5 shows how such flows can be incorporated in the supply and use framing assuming an example where an electricity generator uses wind turbines on cropland to generate electricity.

Table 7.5: Basic Ecosystem services physical supply and use table #4

	Units of measure	Economic units (selected)			Ecosystem assets (selected types)		
		Agri.	Electricity supply	Households	Forest	Cropland	Grassland
SUPPLY							
ES #1: Biomass provisioning services (melons)	Tonnes					80	
ES #2: Air filtration services (PM2.5)	Tonnes				50		
IS: Pollination services	# Visits						2000
AB: Energy from wind power	kWh					10000	
USE							
ES #1: Biomass provisioning services (melons)	Tonnes	80					
ES #2: Air filtration services (PM2.5)	Tonnes			50			
IS: Pollination services	# Visits					2000	
AB: Energy from wind power	kWh		10000				

Notes: Grey cells indicate not applicable. “AB” denotes abiotic flows.

7.2.6 *Exports and imports of ecosystem services*

7.39 The measurement scope for ecosystem accounts is set by the EAA, for example the economic territory of a country including its EEZ. As noted above, for ecosystem services flow accounts this implies a focus on the ecosystem services supplied by all ecosystems within the EAA. There will be a range of situations in which the supply of ecosystem services will not be used by economic units that are resident[76] in the EAA, i.e., exports of final ecosystem services; and also cases where resident economic units use ecosystem services from outside the EAA, i.e., imports of final ecosystem services. There will also be situations in which dependencies between ecosystem assets cross EAA boundaries, i.e., there will be flows of intermediate services. This section discusses the relevant treatments.

7.40 In the following discussion, it is assumed that the EAA concerns a country. In principle, the same considerations can be applied at a sub-national level where the terms exports and imports are applied to flows between, for example, administrative regions. In practice, recording flows among sub-national areas will require significant co-ordination of data although, given the increasing use of GIS techniques, this task may become more manageable.

7.41 Six cases need specific consideration. First, there are people visiting from outside an EAA, for example tourists, who will commonly be users of recreation-related services supplied by ecosystems within the EAA. In this case, measurement requires an allocation of the total supply of the service to that group of people as non-residents, i.e., exports.

7.42 Second, there are many exports (and imports) of biomass and related products (e.g., rice, wheat, timber, fish) between countries. In ecosystem accounting, these flows of products are not considered flows of ecosystem services and hence are not recorded as exports in the ecosystem service flow account. Rather the ecosystem services can be seen to be embodied in the traded products with the flows of products recorded in the standard economic supply and use tables and related balance of payments statistics. Analysis of the extent to which traded products have embodied ecosystem services can be undertaken and this may be an important part of understanding how consumption in one country may have impacts on other countries' ecosystems.

7.43 Third, there are often situations, particularly for regulating and maintenance services, where the users of the ecosystem service are located outside of the ecosystem supplying the service. For example, users of air filtration services provided by forests will usually not live in the forest but in neighbouring communities. Also, the supply of water flow regulation services will often involve a number of ecosystem assets across a catchment to communities located in just one part of the catchment. Where both the supplying ecosystem assets and the location of the users are in the same EAA, then no specific treatment needs to be noted. However, where the location of use is outside the EAA, an export of a final ecosystem service should be recorded to ensure a balance between supply and use. Conversely, where the supply of the service is outside the EAA an import of a final ecosystem service should be recorded.

7.44 Fourth, a sub-set of the ecosystem services considered in the previous paragraph concern ecosystem services that are collective services that are not attributable to individual households or businesses but rather are treated as being used by general government on behalf of the community. The primary example concerns global climate regulation services and, indeed, this service can be considered to be of benefit to all people globally rather than only in a more local, ecosystem asset context. By convention, collective services are recorded as being used by the government that has jurisdiction over the supplying ecosystem assets – i.e., jurisdiction over the EAA – and no exports of collective services are recorded in the system.

7.45 Fifth, consistent with the treatments in the SNA and the SEEA Central Framework, the catching of fish by non-resident operators within a country's EEZ, is treated as production of the non-resident operator. In ecosystem accounting, an export of a biomass provisioning service should be recorded in the supply table recognising the input of that country's ecosystems to

[76] The concept of residency of economic units is applied based on the definitions and principles of the SNA and the Balance of Payments.

the production of other countries. A corresponding import of an ecosystem service should be recorded in the accounts of the country in which the fishing operator is resident.

7.46 Sixth, conceptually, there may be flows of intermediate services between EAA. Examples include fish nursery services provided by one marine ecosystem in one EAA to biomass provisioning services provided in another EAA; and the role of particular ecosystems in supporting the migration of species between countries which underpin recreation-related services. However, these flows should only be recorded in specific circumstances of analytical interest either (i) where the flow of the intermediate service into an EAA (recorded as an import) can be clearly linked to a final ecosystem service supplied by an ecosystem asset within the EAA; or (ii) where the flow of the intermediate service from an EAA (recorded as an export) can be clearly linked to a final ecosystem service supplied by an ecosystem asset outside the EAA.

7.47 Given that the measurement scope of an ecosystem services flow account is determined by the set of supplying ecosystem assets within an EAA, there is generally less focus on imports of ecosystem services which, by definition, are supplied by ecosystems outside of the EAA. Indeed, this reality implies there will likely be a larger measurement challenge in quantifying imports of ecosystem services. Thus, the measurement scope of imports should be determined by identifying flows of ecosystem services that are of particular interest, for example in establishing a more complete picture of the use of ecosystem services by resident economic units. For example, the use of recreation-related services by residents who visit locations outside of the EAA may be of interest. Where imports of final ecosystem services are recorded, they are entered in the supply table and a corresponding use is recorded by type of economic unit in the use table.

7.48 In all cases, appropriate allocation and recording of exports and imports of ecosystem services will require an understanding of the location of supply and use and the residency of the economic units involved. This will be particularly relevant when an ecosystem service is supplied from a combination of ecosystems within a landscape context in which the ecosystems involved are located on different sides of an administrative boundary (e.g., where the administrative boundary is defined by a river). Further discussion on the spatial allocation of the supply and use of ecosystem services is provided in section 7.3.

7.2.7 Recording cultural services

7.49 Cultural services involve an interaction between people and ecosystems. Consequently, the quantification of these services generally reflects measurement of the type, number and/or quality of the interaction. For example, recreation-related services are commonly quantified using the number of visits to a specific natural location. While these measures are not a direct quantification of the ecosystem contribution, they are considered a suitable proxy which can be improved by taking into consideration, as far as possible, the number and length of time of interactions with specific features and characteristics of the ecosystems concerned.

7.50 At the same time, for many cultural services, but primarily for recreation-related services, there are businesses involved in facilitating and supporting interactions between people and ecosystems. Broadly, the types of businesses that are involved either (i) supply access to the ecosystem and/or facilitate activities/experiences within the ecosystem (e.g., covering entry fees, guides, tour operators, etc.); or (ii) supply goods and services to visitors to support their travel to, and time at, an ecosystem (e.g., hotels, restaurants, transport companies, fuel suppliers).

7.51 To varying degrees, all of these businesses can be seen to have a connection to the ecosystem and may be considered to have inputs of ecosystem services in their supply of goods and services to visitors. This interpretation is most appropriate in the context of the first type of business, for which it seems likely that, where payments are made by visitors to those businesses, (i.e., reflecting an economic transaction between visitors and the businesses), there is an implicit payment for an ecosystem service. For transactions involving the second type of business, any ecosystem contribution is likely to be much smaller. For accounting purposes, challenges lie in appropriately distinguishing the ecosystem services within transactions already recorded in the standard economic accounts and identifying the additional contribution of the ecosystem to the overall benefits that arise from people's interactions with ecosystems.

7.52 The recommended treatment for the ecosystem services supply and use account in physical terms is to record a supply and corresponding use for each visitor interaction, with the supply shown from the relevant ecosystem type and households as users of the service. This flow should be recorded irrespective of the degree to which there is involvement of businesses in facilitating or supporting the activity.

7.53 In addition, a supplementary row to the use of ecosystem services should be recorded showing the connection between the ecosystem and relevant businesses. This entry does not imply the need to record additional supply but provides complementary data on the use of ecosystem services. Both entries in the use table reflect final ecosystem services. These entries are shown in Table 7.6 using suppliers of recreation activities as an example of the types of businesses.

Table 7.6: Basic ecosystem services physical supply and use table #5

	Units of measure	**Economic units (selected)**		**Ecosystem assets (selected types)**		
		Recreation services	Households	Forest	Cropland	Grassland
SUPPLY						
ES #3: Recreation related services	# Visits			180		
USE						
ES #3: Recreation related services	# Visits		180			
Supplementary data						
Use of ES#3 by business	# Visits	180				

Notes: Grey cells indicate not applicable.

7.2.8 Linking the supply of ecosystem services to economic units

7.54 The supply and use tables described in this chapter allow for the recording of flows between ecosystem types as suppliers and economic units as users. There may be interest in presenting the data in a complementary way in which the economic units that either own or manage the areas associated with the ecosystem types are shown as suppliers. For example, farmers may be shown as suppliers of biomass provisioning services, global climate regulation services and water flow regulation services reflecting a bundle of ecosystem services supplied by the ecosystem assets within the boundaries of the farms that they own or manage.

7.55 Presentation of data in this way must be done with care since there is no necessary one-to-one link between ecosystem types and economic units. Most commonly, there will be a combination of ecosystem types within a single parcel of land that an economic unit owns or manages. In the first instance then, the starting point for organisation of data on the flows of ecosystem services should follow the approach described in Chapter 4 in the presentation of ecosystem extent data with respect to economic units.

7.56 Using information on the relationship between ecosystem types and economic units, an alternative supply table may be structured, building on Table 7.1a to show under each ecosystem type (e.g., forests), the range of different types of economic units, for example grouped by industry. Another option would be to show for each type of economic unit (e.g., agriculture), the range of ecosystem types they manage. Under either presentation, the total supply of a given ecosystem service from a specific ecosystem type should be the same as that recorded following the structure of the supply table shown in Table 7.1a. Note also that the entries in the use table are unaffected by the alternative presentations of the supply table.

7.57 Beyond presentation in tabular form, the presentation of this type of information in maps by overlaying data about ownership and management by economic units may be particularly useful for some policy and analysis.

7.3 Considerations in accounting for ecosystem services in physical terms

7.3.1 Spatial allocation of ecosystem services supply and use

7.58 A number of ecosystem services, particularly regulating and maintenance services but also some cultural services, are generated at landscape scale in the sense of involving a range of ecosystem assets of different types. Examples include the contributions of different ecosystems to water flow regulation and soil erosion control services which are commonly measured and modelled at a catchment scale rather than for individual ecosystem assets within the catchment.

7.59 For ecosystem accounting, it is appropriate for the measurement of the total supply of an individual ecosystem service to be undertaken at a larger, multi-ecosystem scale in order to get the best estimate of supply. However, the logic of ecosystem accounting further implies the allocation of total supply to the various ecosystem types involved and conceptually, to individual ecosystem assets. This allocation can in turn support, for example, understanding the critical ecosystems within a catchment.

7.60 In addition to the allocation of supply to ecosystem types, there is a general interest in linking the supply and use of ecosystem services to the location of ecosystem assets as reflected in the measurement of ecosystem extent. Such spatial allocation is conceptually feasible since ecosystem services are spatial phenomena.

7.61 Generally, ecosystem services may be supplied from locations that are the same as, or different from, the locations in which they are used and where the benefits are received. Since ecosystem services have varying spatial characteristics and follow certain flow paths (Bagstad et al., 2013; Costanza, 2008), linkages between supply and use can occur via several pathways:

- Some benefits from ecosystem services are received in the same place they are supplied (in situ ecosystem services). Most provisioning services fall in this category.
- Some benefits are received in the surrounding landscape and beyond (omnidirectional ecosystem services). Global climate regulation services are an example in which the benefits are global, but the ecological process can occur in any ecosystem.
- Some benefits are received downstream or downslope from where they are supplied (directional ecosystem services). For example, water may be purified upstream from where the consumption of water occurs. Directional ecosystem services can also

depend on spatial proximity, i.e., where people receive benefits by being near, but not necessarily in, the relevant ecosystem.

7.62 Building on this framing, the following considerations apply in allocating the supply and use of ecosystem services to ecosystem types and to economic units. Provisioning services are treated as supplied and used in the same ecosystem since, in accounting terms, the exchange between ecosystem and economic unit takes place at the point of harvest which must take place *in situ*. Subsequent transactions involving the processing, transportation and sale (including potential export) of harvested materials are the subject of standard economic accounting and are not the focus of ecosystem accounting.

7.63 Regulating and maintenance services are commonly supplied by ecosystems, or combinations of ecosystems, in one location and used by economic units in other locations. Further there are a range of cases where a single service is supplied to a range of different economic units that are present in a single area. Specific examples here concern the services of ecosystems in mitigating the effects of extreme events. For accounting purposes, there remains a need to ensure that total supply and total use are balanced but, in concept, allocation across locations involving multiple ecosystem assets and multiple users can be readily recorded using supply and use tables.

7.64 Many cultural services are supplied and used in situ since they are based on direct interactions between people and ecosystems. Recreation-related services are the clearest example. At the same time, there are a range of cultural services in which there are indirect connections and hence the locations of supply and use will be different. Note that the location of use of the service is not dependent on the location of residence of the user. Users of in-situ ecosystem services may be resident in the ecosystem, near the ecosystem or in another country. In all cases, the location of use is the ecosystem but the differences in residence are reflected in the classes of user that are identified (e.g., through the recording of exports, see section 7.2.6).

7.65 For the purposes of compiling a supply and use table following the structure of Table 7.1, it is necessary to allocate the supply of ecosystem services to ecosystem types but it is not required to (i) allocate that supply to individual ecosystem assets in specific locations; or (ii) to record the location of the economic units using the ecosystem services. However, for a range of purposes, especially to support spatial planning and assessment, attribution of ecosystem services supply and use to locations is likely to be of considerable power. Further, for many ecosystem services, particularly regulating and maintenance services, the compilation methods are likely to involve the use of detailed spatial data in which case allocation to locations can be seen as a by-product.

7.66 The discipline of allocating ecosystem services to locations is known as ecosystem services mapping. Key concepts of relevance for ecosystem accounting are service providing areas (SPA) and service benefitting areas (SBA). For each ecosystem service, the delineation of SPA and SBA provides the location and spatial boundary that will reflect the location of supply and use, respectively. For accounting purposes, it will be appropriate to link SPA with maps of ecosystem extent classified by ecosystem type and to link SBA with information on the location of different types of economic units (businesses, government, households) for example using cadastral information and with users that are resident outside the EAA. Guidance on ecosystem service mapping is available in Burkhard & Maes (2017).

7.3.2 *Determining ecosystem service measurement baselines*

7.67 Entries in the ecosystem service flow accounts reflect a total flow over an accounting period. For example, the total fish caught from marine areas during a year or the total number of plants pollinated. This is different from measuring the change in the flow associated with a particular action (e.g., change in pollination due to reductions in the number of pollinators) or measuring the flows relative to different ecosystem types (e.g., the relative contribution of forests and grasslands in water regulation). To ensure that all accounting entries in the ecosystem service flow accounts refer to a total flow and can be compared across different contexts, ecosystem service measurement baselines (baselines)[77] are used.

7.68 Ecosystem service measurement baselines are directly applied in the measurement of regulating and maintenance services but are implicit in the measurement of all ecosystem services. Thus, for provisioning services and cultural services, where it is possible to observe a direct interaction between people and ecosystems, the implicit baseline is zero. That is, the quantification of the flow implicitly assumes the potential for no harvest or no interaction. The quantification of the ecosystem services is therefore appropriately focused on measuring the number and type of biomass harvested or cultural interactions.

7.69 The identification of regulating and maintenance services involves a focus on the extent to which ecological processes contribute to environmental conditions that are beneficial to people and their activities. These processes may involve remediation or mitigation of a potentially negative impact. For example, air filtration services reduce ambient air pollution concentrations. The negative impacts (i) may be caused by human activities (e.g., most forms of air pollution, greenhouse gas emissions), (ii) may result from natural events (e.g., due to storm surges), or (iii) may result from natural events that have an increased likelihood because of human activities (e.g., increased landslides because of deforestation activity). Not all regulating and maintenance services involve remediating a negative impact. For example, pollination may involve the transfer of pollen to enable plant sexual reproduction. In these cases the implicit measurement baseline is zero, e.g., no transfer of pollen.

7.70 The quantification of the supply of regulating and maintenance services generally depends directly and strongly upon knowledge of the ecosystem type and its key characteristics since the role of the ecosystem in supplying services will vary as the type and characteristics change. Thus, in assessing the extent to which a particular ecosystem provides regulating and maintenance services, it is normal to make an assumption as to what services would be supplied if the ecosystem type or its characteristics were different. For example, forests are better at capturing air pollutants than grasslands, and wetlands with well-structured and diverse vegetation are better at purifying water of pollutants compared to wetlands with little vegetation.

7.71 The comparison of two different ecosystem contexts, one being the measurement baseline, provides a basis for quantifying the role of the ecosystem in supplying a given service. Thus, an ***ecosystem service measurement baseline is the level of service supply with which a regulating or maintenance service provided by an ecosystem is compared in order to quantify the service.***

7.72 For ecosystem accounting, the use of a common measurement baseline ensures comparability across ecosystem types and across different services. The default measurement baseline is zero, i.e., assuming the ecosystem does not supply the regulating service. In cases where a zero level of service supply cannot be modelled or meaningfully identified, the baseline should be the amount of service supplied by bare land (i.e., where the ecosystem has

[77] Other labels that may be applied include reference levels and counterfactuals. The term measurement baseline is preferred for use in this context.

no vegetation cover) or alternative worst-case ecosystem scenario. The application of this default baseline varies by type of service as shown in Table 7.7 and specific cases are discussed below.

7.73 For air filtration, it is possible to define more directly a 'no' or 'zero' air filtration level, and the differentiation is meaningful from a biophysical modelling perspective. In this case it can simply be stated that the baseline is when there is zero air filtration, i.e., zero capture of ambient air pollutant by an ecosystem. Thus, the supply of the ecosystem service is equal to the quantity of pollutant absorbed by the ecosystem.

7.74 In other cases, determining the baseline of no service supply independent of any land cover is difficult. For instance, the soil erosion control service is usually quantified using the Revised Universal Soil Loss Equation (RUSLE).[78] This approach compares actual erosion rates to those for bare land where the erosion rate in bare land is the maximum potential erosion rate (a worst-case scenario) in a given ecosystem, allowing for soil type and erosivity, slope characteristics, rainfall characteristics and land management factors. Thus, in this case, service supply is defined as the reduction in erosion rates compared to bare land and the baseline needs to be bare land since it represents the situation in which there is no ecosystem service supply.

7.75 In general, for services where the focus is on the regulation of flows (e.g., of water, soil), it is not generally possible to assess the service compared to a zero service baseline. This is because the flows will occur regardless of whether a service is being provided. Further, while the biotic components of ecosystems modify and affect the flows (of water, soil), the flows themselves cannot be conceptualized or modelled without there being abiotic components over which the flow occurs. In these cases, the baseline needs to be bare land.

7.76 Finally, in some cases, the use of bare land as the baseline may not be considered to be conceptually very strong, may be counterintuitive, or cannot be meaningfully modelled. The recommendation therefore is to differentiate in a systematic way, between services for which the baseline is bare land and services for which the baseline is zero service supply. Clear communication and explanation of the chosen methods will be required.

[78] For more information see https://www.ars.usda.gov/midwest-area/west-lafayette-in/national-soil-erosion-research/docs/rusle/

Table 7.7: Baselines for selected regulating and maintenance services

Type of service	Baseline	Comments
Global climate regulation services	No/zero carbon retention or sequestrations	
Air filtration services	No/zero air filtration	Following the treatment described in section 6.4.5 the capture of pollutants by bare and rocky surfaces is included as an ecosystem service.
Water flow regulation services	Bare land	Overland and groundwater flows cannot be zero, and the effect of vegetation can only be compared to a situation without vegetation i.e., bare land.
Flood mitigation services	Bare land	Flood risks are influenced by geomorphology and can be reduced by tree cover (e.g., dunes, riparian forests or mangroves along a coast). There is no such a thing as no flood risk in coastal areas and the flood risk of the vegetation can be compared with a situation without vegetation.
Soil erosion control services	Bare land	The service can be quantified by comparing the erosion rate of the current vegetation cover to that in bare land, the difference is the amount of erosion control/sediment retained.
Water purification services	No purification (i.e., no biological breakdown of water pollutants in the ecosystem)	
Pollination services	No/zero pollination	
Rainfall pattern regulation services	Bare land	It is not possible to model rainfall patterns without assuming any rainfall and evapotranspiration across all components of the landscape. The role of vegetation therefore needs to be compared to a situation with no vegetation, i.e., bare land.
Nursery population and habitat maintenance services	No/zero nursery service	

Note: For descriptions of each service refer to Chapter 6, Table 6.2.

SECTION D: Monetary valuation and integrated accounting for ecosystem services and assets

Section overview

A number of motivations exist for estimating the monetary value of the environment's contribution to the economy and people. There is also interest in integrated assessments of the connection between the environment and the economy, in particular understanding changes in broad measures of wealth resulting from human and natural causes, for example, from climate change and biodiversity loss. At the same time, monetary valuation will not be appropriate in all decision-making contexts and, in all cases, it will be relevant to use associated biophysical data on stocks and flows.

Among statisticians, the use of monetary values of environmental stocks and flows in the measurement and assessment of the environment has long been a point of discussion and contention. The existence of multiple perspectives on this issue is well recognised. There are differences of view concerning (i) the underlying framing for valuation of environmental stocks and flows; (ii) the potential of monetary valuation to support decision making; (iii) the ability to produce reliable estimates in monetary terms in practice; and (iv) the role of national statistical offices in producing fit for purpose statistics in this area of measurement.

While these different perspectives exist, there is a role for the exchange value based approach to the monetary valuation of ecosystem services and ecosystem assets described in chapters 8 – 11. The UNSC at its 52nd session recognised chapters 8-11 as describing internationally recognised statistical principles and recommendations for the valuation of ecosystem services and assets in a context that is coherent with the concepts of the System of National Accounts for countries that are undertaking valuation of ecosystem services and/or assets. The UNSC also requested the prompt resolution of outstanding methodological aspects in these chapters as identified in the research agenda.

While, the recommendations in chapters 8-11 on valuation reflect the latest knowledge, methods and techniques to measure and organize information about ecosystems; it is expected that this knowledge, as well as the data sources and techniques used to compile the accounts, will evolve over time as a result of the ongoing implementation of these accounts. Consequently, as with all statistical methodology documents, it will be necessary to refine and revise it in the future.

In describing valuation based on exchange values, the SEEA EA recognizes that this provides monetary values that exclude welfare measures that may be commonly included in monetary values of the environment used in other contexts. Chapter 12 has been drafted to support understanding the connections among the various approaches to measurement and analysis in monetary terms.

More generally, as highlighted in the opening chapters of the SEEA EA, it is emphasized that monetary values from the accounts, and the wider economic values just described, will not fully reflect the importance of ecosystems for people and the economy. Assessing the importance of ecosystems will therefore require consideration of a wide range of information beyond data on the monetary value of ecosystems and their services, including data on their extent and condition, and on the characteristics of the people, businesses and communities that are dependent on them.

It is recognized that there are concerns about estimating monetary values in practice due to data constraints and the application of valuation techniques. These factors will require compilers to consider issues of data quality and uncertainty before compiling and disseminating accounts in monetary terms. It may be appropriate in initial releases to label data in monetary ecosystem accounts as experimental. To support the compilation, application and interpretation of monetary values, a range of technical guidance is available and will be enhanced as part of the research and development agenda of the SEEA EA.

8 Principles of monetary valuation for ecosystem accounting

8.1 The purpose and focus of monetary valuation for ecosystem accounting

8.1.1 The purposes for monetary valuation in ecosystem accounting

8.1 A number of motivations exist for the monetary 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 the concepts, methods and assumptions used for monetary valuation.

8.2 In ecosystem accounting, the primary motivation for monetary valuation using a common monetary unit or numeraire is to be able to make comparisons of different ecosystem services and ecosystem assets that are consistent with standard measures of products and assets as recorded in the national accounts. This requires the use of exchange values. In turn, this facilitates the description of an integrated system of prices and quantities for the economy and the environment that is a core motivation of the SEEA EA.

8.3 Exchange value based monetary valuations can support: comparing the values of environmental assets (including ecosystems) with other asset types (e.g., produced assets) as part of extended measures of national wealth; highlighting the relevance of non-market ecosystem services (e.g., air filtration); assessing the contribution of ecosystem inputs to production in specific industries and their supply chains; comparing the trade-offs between different ecosystem services through consideration of relative prices; deriving complementary aggregates such as degradation adjusted measures of national income; evaluating trends in measures of income and wealth; improving accountability and transparency around the public expenditures on the environment by recognising expenditure as an investment rather than a cost; providing baseline data to support scenario modelling and broader economic modelling; assessing financial risks associated with the environment; and calibrating the application of monetary environmental policy instruments such as environmental markets and environmental taxes and subsidies.

8.4 In the space of environmentally related monetary valuation more generally, it is common for valuation to focus on measurement of the impacts of changes in ecosystem assets and services on economic and human welfare. For example, valuation may focus on measuring the impacts of improved parks and reduced pollution on human health or the impacts of reduced soil fertility on farm incomes. The valuation of impacts, both positive and negative, is an important requirement in the development of specific policy options and policy settings, project evaluation and incentive design. This may include, for example, detailed cost-benefit analysis and the assessment of compensation and damage claims. Such analysis can be complemented, but not replaced, by data from a set of ecosystem accounts based on exchange values, recognizing that is likely that more detailed and finer scale data and valuations are required for impact analysis. More broadly, SEEA EA accounts provide a coherent framing for the collection and organisation of relevant data and can support an understanding of micro-macro linkages and the assessment of changes over time.

8.5 As introduced in Chapter 2, in describing its approach to monetary valuation in Chapters 8 to 11, the SEEA EA is aware that monetary values cannot reflect a comprehensive or complete value of nature and nor are monetary values appropriate for use in all decision-making contexts. The following considerations are of particular relevance noting that they apply to all monetary values, not only the values of ecosystem services and ecosystem assets described in these chapters.

- There are multiple value perspectives, including intrinsic and instrumental values, and the monetary values described here do not encompass all of these value perspectives with respect to ecosystem services and ecosystem assets. Further, for assessing some aspects of nature's value (e.g., spiritual connections) an accounting framework might not be suitable. Nonetheless, data on the physical flows of ecosystem services and on the extent and condition of ecosystem assets may support assessment of some other value perspectives.
- Monetary values are of most applicability in analysing changes that are marginal, i.e., concerning the effects of relatively small changes in stocks or flows of a particular asset, good or service. For example, analysing the changes in agricultural production associated with changes in soil fertility. When there is a requirement to analyse large, non-marginal changes, such as the permanent loss of a water resource, analysis should incorporate the assessment of physical changes in stocks in relation to appropriate thresholds.
- Monetary values for ecosystem services that are not scarce, or that are in excess supply, may be low or even zero based on the exchange value concept. Although this is consistent with this value concept, such values should be interpreted carefully and in conjunction with physical supply and use tables; in particular, because non-scarcity can be a result of regulatory policies or market structures, or may reflect the current relative abundance of the ecosystem type supplying the service.
- Monetary values for non-market goods and services, including, for example, government provided health, education and defence services included in the SNA, cannot be based on directly observed market transactions and hence are valued using alternative methods that approximate the exchange value of the relevant goods and services. Since there is no explicit market, the resulting values cannot reflect precisely the general equilibrium effects that would be expected if a market did exist. The extent to which the various valuation methods will provide a good approximation will vary noting that all methods will reflect prices of a partial equilibrium. It is therefore relevant that as much specificity as possible about the location and context of the transaction is incorporated in the application of alternative methods.

8.6 Overall, while there are many contexts in which monetary values can support decision making, there will also be situations in which non-monetary data will play a primary role. In this regard, the integrated recording of physical and monetary data in the SEEA EA should be of particular benefit.

8.7 This chapter outlines the core principles of monetary valuation used in ecosystem accounting in applying the national accounting concepts for valuation. These principles are articulated to provide a common basis for discussing and interpreting monetary values in ecosystem accounting and to allow the available valuation techniques to be appropriately applied.

8.1.2 The focus of monetary valuation for ecosystem accounting

8.8 Monetary valuation depends on two factors in an accounting context, namely (i) the definition and scope of goods, services and assets included; and (ii) the valuation concept that is used. In ecosystem accounting, the valuation concept that is applied is exchange values. This is the same valuation concept applied in the SNA and hence is a concept that supports comparison and integration with national accounts estimates and a range of analytical and indicator applications as described above.

8.9 As also noted above, the majority of research and policy on environmentally related monetary valuation has been conducted with a focus on measuring changes in welfare, for example as part of cost benefit analysis. A commonly applied framework to assess the economic value of ecosystems is the Total Economic Value framework (Pearce & Turner, 1990). It describes the range of direct use (e.g., biomass harvesting, recreation), indirect use (e.g., air filtration, water regulation) and non-use values (e.g., existence values of specific species) that are relevant in providing a comprehensive assessment of changes in welfare. Within this range of use and non-use values, it is usual to apply monetary valuation techniques that assess values of changes in welfare most commonly approximated using measures that include consumer and producer surplus.

8.10 Generally, where there is a focus of analysis on the inputs of ecosystems to the production of marketed goods and services (SNA benefits), for example agricultural production, there is a good alignment between monetary valuations for accounting or welfare analysis. However, since values recorded in the accounts exclude consumer surplus, monetary valuation undertaken for the purpose of accounting for ecosystem services that contribute to non-SNA benefits will regularly differ from estimates of monetary values obtained in environmental economic studies, potentially by significant amounts. Further, when considering a more aggregated value of an ecosystem, the monetary values obtained from ecosystem accounts will be limited to the coverage of ecosystem services and will be lower due to the exclusion of non-use values.[79] It is therefore important that compilers of accounts document and explain the coverage and conceptual basis for the monetary values being released and that users recognise that not all monetary values are substitutable. In different analytical and decision-making contexts, different monetary values will be relevant.

8.11 While there are differences between monetary valuations responding to different analytical purposes, there are theoretical and practical connections between values recorded in the accounts and welfare values. These connections are summarised in Annex 12.1 to support account compilers in their use of non-market valuation methods for ecosystem services (as described in Chapter 9); and to build a common language among accountants and environmental economists.

8.12 Further, there will likely be important information contained in understanding the gap between accounting values and values obtained using alternative valuation concepts and assumptions. In this way, different monetary values can play complementary roles in supporting decision making. With this in mind, and to complement the exchange value-based approach to the monetary valuation of ecosystem services and ecosystem assets described in Chapters 8 to 11, Chapter 12 introduces a number of complementary approaches to deriving and presenting monetary values concerning the environment and the links to the economy. These approaches include the analysis of externalities and the restoration cost-based approach to the valuation of ecosystem degradation.

8.2 Valuation concepts and principles for accounting

8.2.1 Exchange values and market price concepts in national accounting

8.13 In national accounting, the entries in the accounts in monetary terms reflect their exchange values as defined in the SNA. ***Exchange values are the values at which goods, services, labour or assets are in fact exchanged or else could be exchanged for cash*** (2008 SNA, para. 3.118). This section outlines the related principles from a general national accounting perspective

[79] While non-use values are excluded from values of ecosystem services in the SEEA EA, transactions associated with non-use values such as donations to environmental charities, and payments for eco-friendly products, will be recorded in the standard economic accounts. The separate identification of these values is not considered in the SEEA EA.

and the following sections describe the application of these principles for ecosystem accounting.

8.14 For the vast majority of entries in the national accounts, exchange values are measured using data from observed transactions involving market prices. ***Market prices are defined as amounts of money that willing buyers pay to acquire something from willing sellers*** (2008 SNA, para. 3.119).[80] The use of observed market prices implies that the accounts embody information about the revealed preferences of the economic units involved.

8.15 Observed market prices are defined without expectation that the markets in which exchanges take place satisfy specific institutional arrangements or assumptions. The 2008 SNA observes "*a market price should not necessarily be construed as equivalent to a free market price; that is, a market transaction should not be interpreted as occurring exclusively in a purely competitive market situation. In fact, a market transaction could take place in a monopolistic, monopsonistic, or any other market structure."* (2008 SNA, para. 3.119). Given this, the general interpretation in accounting is that market prices should reflect the current institutional context, i.e., the current market structures and associated legal or regulatory arrangements. Consequently, market prices used in national accounting will likely reflect the presence of various market imperfections from the perspective of economic theory.

8.16 While the majority of transactions recorded in the national accounts are based on observed market prices, there are several (often large) transactions for which market prices are not observed and therefore need to be estimated. Thus, in the national accounts, where market price-based transactions are not observable, alternative methods are used to estimate them and hence allow aggregation across market and non-market goods and services in the measurement of production and consumption.[81]

8.17 The SNA recommends various approaches, summarised below, and much practice has evolved. At the same time, in applying the SNA recommendations, compilers in different countries must consider their local context and institutional structures. For example, markets for the same good in different countries may be loosely or heavily regulated and hence different valuation approaches must be applied. Comparison of national accounts estimates across countries is possible notwithstanding the variation in institutional contexts and methods since the market price principle underpins the exchange values recorded in the accounts.

8.18 Two primary alternative methods are described in the SNA in relation to transactions in goods and services namely (i) market prices of similar or analogous items (adjusted for quality and other differences as required) (2008 SNA, para. 3.123); and (ii) where no appropriate market exists, prices may be derived by the amount that it would cost to produce them currently (2008 SNA, para. 3.135).

8.19 Cost-based techniques are commonly applied in estimating the value of government supplied services including education, health and defence. Indeed, they are required in the context of measuring accounting entries for public goods. In these cases, it may be assumed that the amount of expenditure embodies information about the revealed preferences of a country or community. At the same time, it is accepted that these values for public goods will not reflect the full social benefit arising from the provision of these collectively enjoyed services.

[80] The 2008 SNA notes a number of cases where actual exchange values do not represent market prices (e.g., in situations of transfer and concessional pricing (see paragraphs 3.131-3.134)).

[81] Note that the use of these alternative methods to estimate exchange values highlights that the estimation of exchange values does not require the actual exchange of money (cash or equivalent).

8.20 Transactions in assets are valued using the same approaches just outlined, either based on observed prices (e.g., sales of land) or using the two alternative methods. Exchange values of assets are also required to underpin entries in asset accounts and balance sheets, i.e., exchange values for each asset are required at the opening or closing of the accounting period. The ideal source of exchange values for assets at balance sheet dates are prices observed in markets (e.g., valuing share portfolios using market prices at balance sheet date). Where there are no directly observable prices from markets, the SNA describes two approaches for estimating the exchange value of an asset. The first is the written down replacement cost approach which recognises that the value of an existing asset (most commonly relating to produced assets such as buildings and machinery) at any given point in its life, is equal to "*the current acquisition price of an equivalent new asset less the accumulated depreciation"* (2008 SNA, para. 13.23). The second approach entails using *"the discounted present value of expected future returns"* (2008 SNA, para. 3.137). This second approach is of primary relevance for ecosystem accounting since there are no observable current acquisition prices of ecosystem assets that encompasses the range of ecosystem service values supplied by an ecosystem asset.

8.21 As introduced above, entries in the accounts will usually be an aggregate of multiple transactions in a specific good or service over an accounting period (e.g., all sales of bread in one year) or an aggregate of multiple assets of a specific type at a balance sheet date (e.g., all trucks registered at 31 December). Further, accounting entries are recorded progressively over multiple accounting periods and balance sheet dates. In this way, time series of accounting entries based on exchange values will be compiled for various goods and services and types of assets. All accounting entries are recorded at the respective points in time at their nominal values – i.e., the prices applying at the time of the transaction or balance sheet entry.

8.2.2 Monetary valuation of ecosystem services

8.22 Chapter 2 described the general ecosystem accounting framing in which ecosystem services are supplied by ecosystem assets and where ecosystem assets are established as additional units in a wider accounting system, distinct from the standard economic units such as households and businesses. From a national accounting perspective, flows of ecosystem services from ecosystem assets can be conceptualised in two ways. First, ecosystem assets may be considered as complex, and interacting, producing units that supply outputs of ecosystem services to various users – this reflects the societal benefit perspective described in Chapter 2. Alternatively, flows of ecosystem services may be considered analogous to flows of capital services supplied by produced and non-produced assets as described in 2008 SNA, Chapter 20 – this reflects the asset value perspective from Chapter 2. These two perspectives are reconciled for the purposes of monetary valuation by treating the output of ecosystem assets as producing units as consisting solely of capital services.[82]

8.23 Thus, in concept, ecosystem services should be valued for accounting purposes in a manner aligned with the valuation of capital services in the SNA. This value will be different from the rentals that would be charged following the definitions in the SNA (2008 SNA, para. 6.245). By way of example, the rentals paid by a tenant to a landlord will cover the capital services

[82] For clarification, note that the output associated with the use of ecosystem services (for example, rice production) is distinctly recorded in the accounting system as the output of an economic unit. This economic unit will have intermediate, labour and capital costs that are deducted from output resulting in measures of gross value added and gross operating surplus that are different from output.

provided by the dwelling[83] as well as the direct operating costs (e.g., management and maintenance costs). Hence the output will be measured in terms of the rentals charged to the tenant and the direct costs must be deducted in order to determine the value of the capital services, and equivalently the gross operating surplus.

8.24 Analogously, in ecosystem accounting, ecosystem services are distinguished from the benefits to which they contribute, and hence the focus of valuation is on the contribution of the ecosystem asset (i.e., the input of ecosystem services) and not on the valuation of the benefits.[84] For example, in the valuation of ecosystem services associated with agricultural production, the direct operating and input costs associated with producing an agricultural output (e.g., rice) including fuel, fertiliser, labour and produced assets must be deducted from the value of the output to isolate the value of the ecosystem services.

8.25 For each final ecosystem service, a single capital service flow can be envisaged between an ecosystem asset and an economic unit. Further, since there will be multiple supply contexts, (e.g., air filtration services may be supplied by different ecosystem assets) and different combinations of users (e.g., air filtration services may be used by both households and local building owners), it may be the case that a variety of different capital service flows need to be recorded for the same type of ecosystem service. This includes, for example, the potential to record imports and exports of ecosystem services.

8.26 More significantly, it will be usual for a single ecosystem asset to supply a bundle of ecosystem services. Following the definitions and principles for measuring ecosystem services in physical terms in Chapter 6, separate transactions should be recorded for each type of service supplied to each type of user. The approach thus assumes the separability of ecosystem services. In practice, if bundles of services cannot be clearly separated it will be appropriate to value the bundle as a whole and then apply appropriate allocation methods. This will help reduce the potential for double counting of services.

8.27 In applying national accounting principles to accounting for ecosystems, and particularly in the context of the monetary valuation of ecosystem services, it must be recognised that ecosystem services lie outside the production boundary that defines the scope of measured GDP. Undertaking the valuation of ecosystem services using national accounting valuation principles thus complements and does not replace current national accounting estimates.[85] In this respect, the valuation of ecosystem services is analogous to the compilation of estimates of the value of unpaid household work where such estimates can be compared to, but do not replace, values from the standard national accounts.

8.28 Using a reference to the current SNA production boundary, two valuation contexts can be distinguished. First, in some cases, flows of ecosystem services are inputs to the production of goods and services within the production boundary of the SNA, i.e., SNA benefits. In these cases, the values of ecosystem services are implicitly embodied within values of goods and services recorded in the national accounts. Examples include ecosystem services that contribute to agricultural output, such as biomass provisioning services and pollination by wild bees. Monetary valuation therefore involves partitioning the values of the goods and

[83] These are commonly referred to as "user costs" and include both the consumption of fixed capital and the return on investment (opportunity cost) of the relevant asset.

[84] The selection of terms to convey the relevant concepts can be difficult. Here, the term benefits is used to reflect the concept of output (rentals) and is not intended to be considered in a context of a description of the outcomes or well-being associated with economic activity.

[85] Note that the production boundary of the SNA may change in the future.

services recorded in the national accounts to reveal the ecosystem contribution.[86] The ecosystem service is then recorded as an output of the ecosystem asset and an input of the economic unit that uses the ecosystem service. In a system wide context, value added is unaffected by recording this transaction but both total outputs and total inputs are increased.

8.29 Second, in other cases, ecosystem services contribute to benefits received by economic units including households and governments that are not within the production boundary of the SNA, i.e., non-SNA benefits. For example, air filtration services of forests contribute to cleaner air whose value is not included in national accounts measures of output. In this case, estimating the accounting entries based on exchange values requires (i) determining the prices that would be charged on behalf of the ecosystem asset for the ecosystem services if a market existed; (ii) estimating the costs to obtain an ecosystem service that would need to be incurred by an economic unit to secure the benefits; or (iii) assessing the loss of benefits to an economic unit that would be incurred if ecosystem services were to be lost.

8.30 In practice, the valuation methods used to estimate market prices in the national accounts that were summarised in the previous section can be applied to ecosystem services and assets. In particular, where there are links to SNA benefits, the market prices associated with those benefits provide a clear point of departure for valuation. For ecosystem services that contribute to non-SNA benefits, the market price equivalent and cost-based methods noted earlier may also be used but additional methods are also available to cater to the range of ecosystem services and valuation contexts. Chapter 9, section 9.3, describes the appropriate valuation methods for estimating market price-based exchange values for the compilation of monetary ecosystem accounts.

8.31 Further, in the application of all valuation methods, it will be necessary to consider the range of different contexts that may apply in the supply and use of each ecosystem service across an EAA such as a country. Since market prices are unlikely to be estimated for all transactions in ecosystem services, it will be necessary to apply value transfer techniques that take into consideration variations across location including institutional context and ecosystem type. Section 9.5 discusses the use of value transfer techniques for ecosystem accounting.

8.32 Since the monetary values of ecosystem services are estimated using the exchange value concept and are recorded in the same currency units, it is possible to sum across ecosystem services to derive aggregated measures. Such measures are described in section 9.2.

8.2.3 Monetary valuation of ecosystem assets

8.33 Ecosystem accounting also incorporates recording entries for ecosystem assets based on their exchange values, together with associated changes in the value of ecosystem assets over an accounting period. These changes include ecosystem enhancement, ecosystem degradation, ecosystem conversions and revaluations. This section provides a framing for the valuation of ecosystem assets in monetary terms for ecosystem accounting. Definitions for the changes in ecosystem assets, including ecosystem degradation, are presented in chapter 10, and annex 10.1 outlines the approach to the valuation of these changes.

8.34 The ecosystem assets that are the focus of monetary valuation are delineated following the advice on spatial units and measurement of ecosystem extent as described in chapters 3 and 4. To introduce the valuation principles, the focus is on a single ecosystem asset of a given ecosystem type (e.g., Cool temperate rainforests - IUCN GET class T2.3). An ecosystem asset

[86] In these contexts, the ecosystem contribution may encompass both final ecosystem services and intermediate services recognising that the values of intermediate services will themselves be embodied in the value of the associated final ecosystem service.

is considered to supply a number of ecosystem services (e.g., timber provisioning services, air filtration services, recreation-related services) to different users (e.g., businesses, households, government). Each ecosystem asset will have a different capacity to supply ecosystem services that is closely linked to its extent and condition but will also be linked to existing and expected patterns of ecosystem management and use and to the influence of wider environmental factors such as climate change and extreme events.

8.35 The approach adopted for ecosystem accounting is to value ecosystem assets using a net present value approach. The ***net present value (NPV) is the value of an asset determined by estimating the stream of income expected to be earned in the future and then discounting the future income back to the present accounting period*** (SEEA Central Framework, para. 5.110). In ecosystem accounting, it is applied by aggregating the NPV of expected future returns for each ecosystem service supplied by an ecosystem asset. The use of an NPV approach implies that the value of an ecosystem asset will be related to its capacity to supply ecosystem services and how this capacity is expected to change in the future. The capacity and expected changes in capacity will also reveal information on the expected life of the ecosystem asset. If the use of ecosystem services from an ecosystem asset is considered sustainable, i.e., there is no expected decline in condition, then the asset life will be infinite.

8.36 Application of the NPV approach requires measuring the expected future returns for each ecosystem service and applying a discount rate such that the future returns can be expressed in current period values. The selection of a discount rate can have a large effect on the estimated monetary values. Chapter 10 has a dedicated discussion on this topic.

8.37 To measure the expected future returns there are a number of considerations described in more detail in chapter 10. These include (i) the scope of the returns (i.e., the number of ecosystem services to be included); (ii) the future patterns of flows in physical terms of each ecosystem service taking into consideration expected degradation and patterns of demand; (iii) the expected future prices for each ecosystem service; (iv) the expected institutional arrangements; and (v) the expected asset life. Together with the discount rate, all of these factors are combined to yield an estimated NPV for each ecosystem service at a given point in time. The NPV of the ecosystem asset is equal to the sum of the NPV for each service.

8.38 The description of the NPV approach at the level of an individual ecosystem asset implies the availability of data that can attribute the supply of ecosystem services to that level of detail and hence variations in context and location can be taken into account. In practice, it may not be possible to undertake valuation at this scale and instead valuation by ecosystem type may be undertaken. While the same theory and approach applies at more aggregated scales, it will be necessary to ensure that variations between contexts and location are considered, including changes in institutional context. These variations may impact on the appropriateness of valuation methods and assumptions and on the way in which value transfer techniques can be applied. For example, where measurement is undertaken for all woodlands within a country, the value of recreation-related services provided by the woodlands should take into consideration the variations in distance from population centres.

8.39 Further, as in the monetary valuation of ecosystem services, this approach assumes that the expected future returns for each ecosystem service are separable. It is nonetheless recognised that since there is a bundle of services from a single ecosystem asset, determining the expected future flows for each service requires consideration of the relationships among ecosystem services. Thus, factors influencing the future supply of one ecosystem service will be linked to the future supply of other ecosystem services and expected patterns in the use of some ecosystem services will have direct implications for the potential availability of other ecosystem services. For example, regular use of a forest for harvesting timber will likely reduce the supply of global climate regulation services from the same forest. These considerations will also apply across ecosystem assets which will also have relationships among each other.

8.40 The application of the NPV approach does not require an assumption concerning the economic ownership of the ecosystem asset itself. Such an assumption is only required when integrating monetary values into the standard sequence of institutional sector accounts; a step described in chapter 11. Nonetheless, there is often interest in understanding the relationship between ecosystem asset values and the economic ownership of associated spatial areas – particularly land. This relationship can be analysed by utilising data from the ecosystem extent account and associated data on land ownership and land tenure.

8.41 For some ecosystem assets, primarily anthropogenic ecosystem types such as cropland and urban areas, there are active property markets that reveal prices for the areas. Generally, these prices will not incorporate all ecosystem services supplied from that property and hence they should not be used directly to value an ecosystem asset. At the same time, it is likely that for certain ecosystem services, particularly provisioning services, there is a correlation between the market prices of properties (or the associated rental prices) and the prices of the associated ecosystem services. Valuation methods that utilise this type of market information are described in chapter 9.

8.42 Beyond the valuation of ecosystem assets at balance sheet dates, chapter 10 also provides recommendations to value other ecosystem flows such as ecosystem enhancement, ecosystem degradation, ecosystem conversions, other changes in the volume of ecosystem assets (including catastrophic losses) and revaluations.

8.43 While there are complexities in the measurement of ecosystem asset values and changes in values in monetary terms, the underlying accounting logic is consistent with that used in the SNA and the SEEA Central Framework in relation to the valuation of natural resources such as timber and mineral and energy resources. The general principles are also aligned with those used in the measurement of the capital stock of produced assets as described in the SNA. Consequently, compilers familiar with the valuation of natural resources and the implementation of perpetual inventory models should recognise many of the requirements in relation to the valuation of ecosystem assets.

8.2.4 Volume and price measures

8.44 The analysis of nominal values (i.e., estimates expressed in prices of the accounting period) can be of interest, for example, to understand the relative structure of consumption or production, or to compare levels of expenditure to budget and fiscal constraints. In addition, for many analytical purposes, it is standard practice to also separate (or decompose) changes in accounting entries recorded at two points in time into changes associated with price and those associated with changes in volumes, reflecting both changes in quantity and quality[87]. Following decomposition, a time series is derived that excludes the effects of price changes, i.e., a time series of changes in volumes. These estimates are commonly referred to as constant price measures.[88]

8.45 Since prices for most ecosystem services are not observable, standard practices for estimating price and volume measures which rely on the use of price indexes cannot be applied. A

[87] The term volume is used in accounting since for many goods, services and assets, changes may be due to changes in quality, in addition to quantity and price. In accounting, volume reflects the combination of quantity and quality.

[88] There is an extensive literature on the theory and application of index numbers to accounting. The core elements are described in 2008 SNA, Chapter 15.

particular consideration may be the extent of spatial variation in prices for ecosystem services. While other techniques might be considered, at this stage, it is not recommended that compilers aim to develop volume estimates of ecosystem services and ecosystem assets in a manner aligned with estimates in the national accounts.

8.46 At the same time, since much economic analysis is undertaken using data that excludes price effects, it may be relevant to adjust the aggregate nominal values of ecosystem services and ecosystem assets using a general measure of economy wide price change, such as the consumer price index or GDP deflator. The resulting estimates are commonly referred to as "real measures" in the national accounting literature.

9 Accounting for ecosystem services in monetary terms

9.1 Introduction

9.1 Recording monetary values for ecosystem services underpins the compilation of two of the ecosystem accounts: the ecosystem services flow account in monetary terms and the monetary ecosystem asset account. This chapter describes the ecosystem services flow account in monetary terms as well as approaches to the valuation of ecosystem services for ecosystem accounting applying the principles described in chapter 8.

9.2 The ecosystem services flow account in monetary terms records the monetary value of flows of ecosystem services based on their exchange values. The data from this account can be used to understand the relative economic significance of different ecosystem services (within the valuation framing of the national accounts); support aggregation of ecosystem services to compare the role of different ecosystem assets; understand changes in monetary value over time; underpin comparison of the inputs of different ecosystem services to different users; and support understanding the role of ecosystem services in different locations, e.g., across countries. In addition, the use of exchange values in an accounting context requires drawing clear links between the supply of ecosystem services and the users of ecosystem services. Establishing these links can highlight the economic costs arising from the loss of ecosystem services and highlight the role of government as a provider of public goods.

9.3 While the monetary values described here will fulfil a range of analytical needs, the valuation approach applied in ecosystem accounting does not provide a comprehensive measure of the value of nature. Further, the aggregate monetary values discussed in this chapter will likely reflect a sub-set of all ecosystem services, since common practice will be to commence work on valuation by compiling estimates for a limited number of ecosystem services. Further, as described in section 8.1.2, monetary values based on exchange values will exclude measures of consumer surplus that may be of analytical interest in some contexts. Chapter 12 considers complementary approaches to valuation.

9.4 Entries in the ecosystem services flow account in monetary terms are recorded in line with the definitions, treatments and measurement boundaries for ecosystem services in physical terms described in chapters 6 and 7. Key features of these treatments are discussed in section 9.2. As noted in chapter 8, the monetary valuation of ecosystem services requires the use of various valuation methods since, in many cases, prices for ecosystem services cannot be observed on markets. There is a wide range of environmental valuation methods that have been developed but not all are suitable for application in an accounting context. Section 9.3 summarizes and prioritizes the methods that can be applied and section 9.4 introduces the ways in which different methods can be applied for different types of services. Section 9.5 introduces the topic of value transfer which will be an important step in compiling monetary values for ecosystem services at larger scales since it is unlikely that prices for all ecosystem services in all locations can be estimated directly.

9.2 Ecosystem services flow account in monetary terms

9.5 Estimates of the monetary value of ecosystem services are recorded in the ecosystem services flow account in monetary terms. This account follows the structure of a supply and use table and has the same underlying structure as the ecosystem services flow account in physical terms described in chapter 7. A supply and use table format is used to record flows of different types of ecosystem services between ecosystem assets and economic units. The structure, classification and labelling of the various components (e.g., concerning ecosystem services and ecosystem assets) should be consistent between the physical and the monetary accounts.

9.6 The set of ecosystem services included in the monetary ecosystem services flow account should generally align with the set of ecosystem services included in the physical ecosystem services flow account. However, it is possible that some flows of ecosystem services are considered more difficult to value in monetary terms and hence the number of ecosystem services included in monetary terms may be smaller.

9.7 It is important that compilers document the scope of the ecosystem services included in the accounts and highlight ecosystem services that have been excluded from the scope of measurement and valuation. This is required so that users of the accounts can readily understand and interpret the aggregate measures of the monetary value of ecosystem services. Further, it highlights that data about ecosystem services in physical terms will remain relevant for decision making.

9.8 The basic framing of a monetary ecosystem services flow account is shown in Table 9.1a and 9.1b. The primary scope of the account is determined by the set of ecosystem assets located within the EAA. These are considered the suppliers of the ecosystem services. The set of users included in the account is focused on different types of SNA economic units (i.e., businesses, governments, households) that are resident in the EAA. In addition, the use table also allows for recording use by non-resident economic units (i.e., those economic units who are resident outside the EAA);[89] and for use by other ecosystem assets (i.e., flows of intermediate services). This scope of users is required to ensure that the supply of ecosystem services by resident ecosystem assets can be fully allocated.

9.9 Flows of intermediate services must be recorded as part of a chain of flows that results in a final ecosystem service following the advice described in Chapter 7, i.e., intermediate services are inputs used by ecosystem assets to supply final ecosystem services. In monetary terms, total supply of ecosystem services (recorded in Table 9.1a) will be increased through the recording of intermediate services. This is offset by recording use of ecosystem services by ecosystem assets (in Table 9.1b) distinct from entries pertaining to final ecosystem services which are used by economic units. There is no double counting that results from recording intermediate services in this way. Note that in a given chain of flows, the ecosystem type recorded as using the intermediate service should also be the ecosystem type recorded as supplying the related final ecosystem service.

9.10 The supply and use framework also allows for recording the use of ecosystem services by resident economic units in cases where these services are supplied by ecosystem assets that are located outside the EAA. For example, members of resident household units may travel to other countries and receive cultural ecosystem services in those countries; and resident economic units may receive regulating services such as flood control services that reflect contributions from ecosystem assets outside their EAA. These are recorded in Table 9.1a in the column "supply from non-resident ecosystem assets – imports". Chapter 7 provides an extended discussion on the treatments concerning exports and imports of ecosystem services.

[89] The definition of resident and non-resident economic units follows the definition and treatments of the SNA and the Balance of Payments, In broad terms, an economic unit is determined to have residency in a given economic territory if it has a centre of economic interest in that territory.

Table 9.1a: Ecosystem services supply and use account in monetary terms – supply table

			Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																					
			Terrestrial												Freshwater			Marine						
			T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				…		T7		F1	…	FM1	M1	…	MFT1				
			Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	…	Temperate pyric sclerophyll forests and woodlands	…	…	…	Derived semi-natural pastures and old fields	Permanent upland streams	…	Intermittently closed and open lakes and lagoons	Seagrass meadows	…	Coastal saltmarshes and reedbeds	**Total Supply resident ecosystem assets**	Supply from non-resident ecosystem assets - Imports	**Total Supply ecosystem services**	**TOTAL SUPPLY**
SUPPLY			T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	…	T2.6	…	…	…	T7.5	F1.1	…	FM1.3	M1.1	…	MFT1.3				
Selected ecosystem services (reference list)																								
Provisioning services																								
	Biomass provisioning	Crop provisioning																						
		Grazed biomass provisioning																						
		Livestock provisioning services																						
		Aquaculture provisioning services																						
		Wood provisioning services																						
		Wild fish and other natural aquatic biomass provisioning services																						
		Wild animals, plants and other biomass provisioning services																						
	Genetic material services																							
	Water supply																							
	Other provisioning services																							
Regulating and maintenance services																								
	Global climate regulation services																							
	Rainfall pattern regulation services																							
	Local (micro and meso) climate regulation services																							
	Air filtration services																							
	Soil quality regulation services																							
	Soil and sediment retention services																							
	Soil waste remediation services																							
	Water purification services																							
	Water flow regulation services																							
	Flood control services																							
	Storm mitigation services																							
	Noise attentuation services																							
	Pollination services																							
	Biological control services																							
	Nursery population & habitat maintenance services																							
	Other regulating and maintenance services																							
Cultural services																								
	Recreation-related services																							
	Visual amenity services																							
	Education, scientific and research services																							
	Spiritual, artistic and symbolic services																							
	Other cultural services																							
TOTAL SUPPLY																								

NB: The list of ecosystem services presented is indicative only. In due course the table will include an agreed set of ecosystem services.

Table 9.1b: Ecosystem services supply and use account in monetary terms – use table

			Selected economic units															Selected ecosystem types (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																					
			Selected industries															Terrestrial												Freshwater			Marine						
																		T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1				
			Agriculture	Forestry	Fisheries	Mining and quarrying	Manufacturing	Electricity, gas, steam and air conditioning supply	Water supply; sewerage, waste management and remediation activities	Services	Other industries	**Total Industry**	Government consumption	Household consumption	**Total use by resident economic units**	Exports - final ecosystem services	**Total Use by economic units**	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	...	Temperate pyric sclerophyll forests and woodlands	...	...	...	Derived semi-natural pastures and old fields	Permanent upland streams	...	Intermittently closed and open lakes and lagoons	Seagrass meadows	...	Coastal saltmarshes and reedbeds	**Total use resident ecosystem assets**	Exports - intermediate services	**Total Use by ecosystem assets**	**TOTAL USE**
USE																		T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3				
Selected ecosystem services (reference list)																																							
Provisioning services																																							
	Biomass provisioning	Crop provisioning																																					
		Grazed biomass provisioning																																					
		Livestock provisioning services																																					
		Aquaculture provisioning services																																					
		Wood provisioning services																																					
		Wild fish and other natural aquatic biomass provisioning services																																					
		Wild animals, plants and other biomass provisioning services																																					
	Genetic material services																																						
	Water supply																																						
	Other provisioning services																																						
Regulating and maintenance services																																							
	Global climate regulation services																																						
	Rainfall pattern regulation services																																						
	Local (micro and meso) climate regulation services																																						
	Air filtration services																																						
	Soil quality regulation services																																						
	Soil and sediment retention services																																						
	Soil waste remediation services																																						
	Water purification services																																						
	Water flow regulation services																																						
	Flood control services																																						
	Storm mitigation services																																						
	Noise attentuation services																																						
	Pollination services																																						
	Biological control services																																						
	Nursery population & habitat maintenance services																																						
	Other regulating and maintenance services																																						
Cultural services																																							
	Recreation-related services																																						
	Visual amenity services																																						
	Education, scientific and research services																																						
	Spiritual, artistic and symbolic services																																						
	Other cultural services																																						
TOTAL USE																																							

NB: The list of ecosystem services presented is indicative only. In due course the table will include an agreed set of ecosystem services.

9.11 The entries recorded in the supply and use table should be based on the exchange value concept, apply a common currency unit and pertain to a single accounting period in which accounting entries are recorded in the prices of that period (i.e., nominal values). Separate supply and use tables can be compiled for different accounting periods to record a time series for the ecosystem service flows.

9.12 Generally, entries recorded in the monetary ecosystem services flow account should correspond directly to those recorded in the physical ecosystem services flow account described in chapter 7. Thus:

- The definition and measurement scope of each ecosystem service is the same as in the physical supply and use table, including the treatment and recording of intermediate services, imports and exports of ecosystem services, subsistence production of agricultural and related products and abiotic flows.
- The flow recorded in physical terms should be consistent with the entry in monetary terms; i.e., examination of the accounts in physical and monetary terms should support a coherent picture of supply and use of ecosystem services.
- The allocation of ecosystem service supply to the various users of ecosystem services is consistent with the allocation in the physical supply and use table. Note that the user should not be determined on the basis of the choice of valuation method.
- The accounting period is the same as that for the physical supply and use table.

9.13 Generally, accounting entries for each ecosystem service will be obtained by multiplying a measure of the service flow in physical terms by a price estimated using an appropriate method among those described in section 9.3. However, it will be common that data are not available for all transactions. Thus, it will be necessary to estimate values for ecosystem services using value transfer techniques which account for differences in environmental and socio-economic contexts. The use of value transfer techniques involves a range of assumptions concerning the variation of prices of ecosystem services in different locations. Relevant issues concerning these techniques are discussed in section 9.5.

9.14 Where the accounting entry is measured directly rather than by using separate price and quantity estimates, an estimate of the corresponding flow in quantitative terms should still be included in the physical supply and use table. This will serve to maintain coherence in the accounting system and will support assessment of changes in the ecosystem asset, including for example, ecosystem degradation.

9.15 It is possible to derive aggregate measures of ecosystem services since the entries in monetary terms are in a common currency and are measured using the common value concept of exchange values. For example, for a bundle of ecosystem services supplied by an ecosystem type (e.g., all ecosystem services supplied by forests within an EAA); or for a bundle of ecosystem services used by an industry (e.g., the use of ecosystem services by the fishing industry). Note that the total value of all final ecosystem services supplied by ecosystems within an EAA will include exports of final ecosystem services.

9.16 The structure of Table 9.1a suggests that the supply of each ecosystem service is presented by ecosystem type. Most commonly in practice, as discussed in chapter 6, flows of several ecosystem services are measured spatially using ecosystem modelling and geospatial data techniques as introduced in chapter 7. Consequently, the presentation in the supply table implies the attribution of ecosystem service flows to ecosystem type (e.g., by overlaying maps of individual ecosystem service supply with a map of extent by ecosystem type). Further, where a spatial approach is applied, it will be possible to disseminate maps of different ecosystem services showing where they are supplied within an EAA as separate outputs supporting the ecosystem service supply table. Note that where maps are compiled with data in monetary terms this will require a clear articulation of the approach taken to estimating prices for ecosystem services across the EAA.

9.17 Aggregate measures of ecosystem services in monetary terms can be derived by summing across columns (i.e., to estimate the total supply or use of a single service) and by summing across rows (i.e., to estimate the total supply by an ecosystem type or the total use by type of economic unit). Aggregate measures may be of particular interest in making comparisons to measures of output, intermediate consumption and value added in the standard national accounts, including at an industry level, e.g., for agriculture.

9.18 Using a focus on the total contribution of ecosystem assets within an ecosystem accounting area, such as a country, the aggregate measure ***gross ecosystem product (GEP) is equal to the sum of all final ecosystem services at their exchange value supplied by all ecosystem types located within an ecosystem accounting area over an accounting period less the net imports of intermediate services.***[90] In cases where the net imports of intermediate services, i.e., imports less exports of intermediate services, i.e., imports less exports of intermediate services (see section 7.2.6) are small, GEP may be assumed to be the sum of final ecosystem services supplied by the EAA.

9.19 The scope of GEP covers ecosystem services, including provisioning, regulating and maintenance and cultural services and excludes the monetary value of abiotic flows, spatial functions and non-use values. More generally, the monetary value of abiotic flows and spatial functions should be excluded from monetary aggregates concerning ecosystem assets, for example, in the monetary ecosystem asset account. While excluded from monetary aggregates, abiotic flows and spatial functions can be recorded in supply and use tables in both physical and monetary terms.

9.20 Completing the entries in the use table (Table 9.1b) does not require recording the location of the user. That is, it is sufficient to record the type of economic unit, whether the unit is resident or non-resident, and the relevant class (e.g., type of industry). Nonetheless, the location of users relative to the location of the supplying ecosystem asset will need to be known in ensuring that the estimation of prices is aligned with the spatial context.

9.3 Techniques for valuing transactions in ecosystem services

9.3.1 Introduction

9.21 Section 8.2 describes the conceptual basis for valuing ecosystem services for ecosystem accounting. Since prices for ecosystem services are not generally observed, a range of methods have been developed for estimating them. This section describes the methods that support the derivation of prices for ecosystem services that are consistent with exchange values and hence can be used to provide estimates for entry into the accounts.

9.22 This section describes the methods in a preference order indicating those that are considered to align most closely to the target valuation concept of market prices. For accounting purposes, there is a strong preference for using methods that translate observable and

[90] This definition reflects a production based approach (i.e. outputs less inputs) to determining the contribution of the ecosystems of an EAA to benefits and well-being. Also note (i) that the supply of final ecosystem services will include exports to non-resident economic units; and (ii) imports of final ecosystem services are not included in this measure as they are contributions by ecosystems located in other EAA. The measure is “gross” in the sense of not deducting any associated ecosystem degradation arising in the supply of the services. The measurement of GEP has been actively pursued in China, see for example Ouyang et al. (2020).

revealed prices and costs (i.e., for related or similar goods and services) into the values required for accounting purposes.

9.23 The general advice of the SNA (chapter 3) is that where directly observed market prices are not available, they may be estimated by prices from similar markets; from related markets or using costs of production. Following a similar framing, it is recommended that valuation methods are applied in the following order.

i. Methods where the price for the ecosystem service is directly observable;

ii. Methods where the price for the ecosystem service is obtained from markets for similar goods and services;

iii. Methods where the price for the ecosystem service is embodied in a market transaction;

iv. Methods where the price for the ecosystem services is based on revealed expenditures (costs) for related goods and services;

v. Methods where the price for the ecosystem service is based on expected expenditures or markets.

9.24 The various methods across these five groups are described below. In addition, some other methods that have been applied in environmental valuation contexts are briefly summarized but they are not recommended for use in a SEEA EA context without appropriate adjustment to align results with the exchange value concept. In all situations, the documentation of the data sources, methods and assumptions used should be made publicly available.

9.25 Some methods are more suited to the valuation of certain ecosystem services than others. For example, it is more likely that exchange values for provisioning services will be able to be estimated based on observed market transactions. The matching of methods to different types of ecosystem services is considered further in Section 9.4 and discussed in more detail in the *Guidelines on Valuation of Ecosystem Services and Ecosystem assets* (UNSD, n.d.-b, forthcoming).

9.26 The valuation methods described in this section have been developed in the context of valuing final ecosystem services, i.e., with a focus on the contribution of ecosystems to economic and human activity. Where intermediate services are recorded, the same valuation methods can be applied since there remains the intent to measure the contribution of the ecosystem to economic and human activity. For example, where flows of pollination services are recorded as inputs to biomass provisioning services, both of these services can be valued in terms of their contribution to the associated agricultural output.

9.27 In a SEEA EA context, the aim is to record entries in the accounts for multiple ecosystem services across multiple ecosystem types. In principle, aggregation across ecosystem services and ecosystem types is possible even where different valuation methods are used, provided the different methods are focused on applying the same target valuation concept. This principle is also applied in the national accounts to aggregate across market and non-market goods and services.

9.3.2 Methods where the prices are directly observable

9.28 **Directly observed values**. The most direct method for measuring prices and estimating values for the accounts is based on the direct observation of exchanges in ecosystem services when they are available. For example, if a wetland provides services of water purification and the owners or managers of that wetland are able to charge the water company that abstracts the water for municipal uses, there is a transaction in ecosystem services provided by the ecosystem that can be recorded. Stumpage values charged to timber logging businesses are also an example of directly observed values. Another example of directly observed values is land rental prices in agriculture where markets exist to rent land for crop production or grazing. These rental prices may be used to derive prices for accounting purposes for the relevant biomass provisioning services. In all of these examples, there is a direct link to SNA benefits.

9.29 While the use of directly observed values is the most preferred method, the resulting prices may provide accounting entries for the value of ecosystem services that might be considered low, i.e., where the monetary value of the contribution of the ecosystem is negligible. It is fundamental to recognise that this result is most likely a reflection of the existing institutional arrangements and is a result that is well-understood in the economic literature. For example, it is well documented that the resource rents for natural resources that are extracted in open-access contexts will tend to zero (Hartwick & Olewiler, 1998).[91]

9.30 Nonetheless, provided the prices are from institutional arrangements that are sufficiently mature and large, the resulting prices should still be applied in ecosystem accounting since the core intent to show accounting entries that reflect the established market context and hence support analysis of the prices relative to those of other services and assets. To the extent that the recorded values are considered "low", there may then be an interest in estimating complementary values on the basis of alternative institutional contexts and market settings. These hypothetical values should not be recorded in ecosystem accounts but may be presented in complementary accounts (see chapter 12).

9.31 Prices may also be observed in relation to non-SNA benefits. For example, payments for ecosystem services (PES) may provide a direct measure of the value of ecosystem services. In certain circumstances this will be true and the payments, for example from a government agency to a land manager, will embody an appropriate price for a particular service for accounting purposes. However, most commonly, payments for ecosystem services and the associated institutional mechanisms are not designed to reveal prices for specific services. Instead, they are aimed at either supporting land managers in undertaking ecosystem restoration work or similar practices, or are aimed at implementing broader government social policies, for example concerning income support. Generally, the advice is not to use data from payments for ecosystem services schemes in the estimation of prices for ecosystem services, unless there is clear evidence that the scheme does target a specific service.

9.32 A specific market concerns observed prices from emission trading systems which may be used to estimate prices for global climate regulation services based on carbon retention. The number of countries with such trading systems is increasing, as is the quantity of carbon being traded and hence these markets may provide suitable price data.[92] If the trading system is not considered sufficiently mature, an alternative is to use data on the marginal costs of abatement, which is more widely available,[93] or data on the social cost of carbon when derived from models that are consistent with the exchange value concept, i.e., limited to assessment the effects on measures of output.

[91] An assumption made here is that there is also an increasing scarcity of the underlying resource. Where there is no scarcity, a low or zero price would be appropriate.

[92] Ideally the observed price from the emission trading system should be adjusted to take into account the impact that including the removals of carbon by the forestry sector would have on the price. The depth and maturity of these market should also be considered in these contexts.

[93] These costs vary by sector so the highest cost should be taken as the overall marginal cost of abatement.

9.33 Note that the SNA does not require that prices originate from competitive markets, for example, transactions based on prices from monopolistic or oligopolistic markets are recorded in the national accounts without adjustment. However, where directly observed prices are considered not economically significant[94] (such cases may arise in the context of fees paid to enter a national park, for example), the observed price should not be used and alternative valuation methods should be applied. Further, care should be taken to understand the size of markets and their maturity. The use of prices from small or immature markets may not be sufficiently representative for use in ecosystem accounting.

9.3.3 Methods where the prices are obtained from markets for similar goods and services

9.34 **Prices from similar markets**. When market prices for a specific ecosystem service are not observable, valuation according to market price equivalents may provide an approximation to market prices. Following the SNA, *"Generally, market prices should be taken from the markets where the same or similar items are traded currently in sufficient numbers and in similar circumstances. If there is no appropriate market in which a particular good or service is currently traded, the valuation of a transaction involving that good or service may be derived from the market prices of similar goods and services by making adjustments for quality and other differences"* (2008 SNA, para. 3.123).

9.35 For example, when non-wood forest products (e.g., mushrooms) from one forest are marketed but those from a similar forest are not, the prices observed in the former can be used to value the non-wood forest products from the latter, allowing for differences in products and other factors. In applying this method, the price from the similar market will need to be adjusted for any costs incurred to supply the good or service to ensure the price used refers to the ecosystem service. Implicitly, it is assumed that the flows of (non-marketed) ecosystem services (in this example the harvest of mushrooms) are not significant enough such that they would alter the observed price of, and demand for, the good or service from the similar market. Note also that prices from similar markets will reflect prices of the existing institutional context in the same way as the directly observed values method.

9.3.4 Methods where the prices (and associated values) are embodied in market transactions

9.36 **Residual value and resource rent methods.** The residual value and resource rent methods[95] estimate a value for an ecosystem service by taking the gross value of the final marketed good to which the ecosystem service provides an input and then deducting the cost of all other inputs, including labour, produced assets and intermediate inputs (see formula from the SEEA Central Framework below). Depending on the scope of the data (e.g., pertaining to a specific location or to the activities of an industry as a whole), the estimated residual value provides a direct value that can be recorded in the accounts or can be used to derive a price that may be applied in other contexts. The relevant considerations in deriving a price are described in the SEEA Central Framework (annex 5.1).

[94] The relative significance of prices is considered in the SNA in the following way. *"Economically significant prices are prices that have a significant effect on the amounts that producers are willing to supply and on the amounts that purchasers wish to buy"* 2008 SNA, para. 22.28.

[95] While similar in intent, there is a distinction between these methods in that the resource rent method will reflect an aggregate value of the rent in a given circumstance while the residual value method focuses on calculating the rental price, where the rent was determined in a market with a fixed supply and a competitive demand.

Output less intermediate consumption less compensation of employees less other taxes on production plus other subsidies on production **Equals gross operating surplus** less consumption of fixed capital (depreciation) less return on produced assets less labour of self-employed persons **Equals resource rent** = depletion + net return on environmental assets

9.37 In practice, there can be a number of difficulties in applying these methods. First, the residual may reflect a combination of other non-paid and indirect inputs and thus distinguishing the ecosystem service contribution may be difficult. Second, the estimate is subject to errors in calculating the value of all the ´paid´ inputs. Third, the size of the residual will be directly affected by the institutional arrangements surrounding the use of the ecosystem. Finally, it is noted that this method is often most readily applied using broad, industry level data and the resulting price estimates may lack the granularity required for developing location specific monetary values. At the same time, since this method is applied based on observed data, the values and prices estimated using this technique will reflect the current institutional context and may provide a high-level framing for monetary values.

9.38 **Productivity change method**. In this method, the ecosystem service is considered an input in the production function of a marketed good. Thus, changes in the service will lead to changes in the output of the marketed good, holding other things equal. The value of the service is derived in three stages. First, the marginal product (contribution) of the ecosystem service is estimated as the change in the value of production consequent upon a marginal change in the supply of the ecosystem service. Second, the marginal product is multiplied by the price of the marketed good to derive a marginal value product for the ecosystem services. Third, this marginal value product is multiplied by the physical quantity of the provided ecosystem service to obtain the value of the ecosystem service. The relationships should be estimated for a single accounting period recognising that they may change over time.

9.39 The productivity change method has been used to price the services provided by water and other inputs in agriculture, e.g., pollination, across locations where detailed data to estimate production functions are available. It is particularly suited for the valuation of ecosystem services that are inputs to existing SNA outputs. However, where there are multiple goods and ecosystem services involved, specifying the production function and marginal product of an individual ecosystem service may be difficult since there will be a range of factors that need to be factored in. Further, the method can be data intensive and scaling up to a national level may be difficult.

9.40 **Hedonic pricing method**. The hedonic pricing method estimates the differential premium on property values or rental values (or other composite goods) that arises from the effect of an ecosystem characteristic (e.g., clean air, local parks) on those values. This method is commonly used to measure services related to the amenity provided to residents in particular locations. In order to obtain a measure of this effect, all other characteristics of the property (including size, number of rooms, central heating, garage space, etc.) are standardized and need to be included in the analysis. Consideration should also be given to the geographical, neighbourhood and ecosystem characteristics of the properties.

9.41 In the context of ecosystem accounting, the decomposition of these values into the part explained by the ecosystem characteristic and the part explained by the remaining characteristics of the property can be used to estimate a value for the relevant ecosystem service (e.g., air filtration, recreation-related services) for a specific property. Where the hedonic pricing method is applied to property values rather than rental values, the resulting prices need to be converted to relate to an annual service flow using a suitable rate of return.

9.42 Estimated prices for the ecosystem service can be applied in other locations, for example by deriving prices per hectare. This method may also be considered for use in other property or rental value contexts such as for agriculture land sales or rentals in the context of biomass provisioning services.[96]

9.43 Hedonic pricing will reveal a value for accounting purposes only in the case of a fully-informed and fluid market, where buyers are able to find properties with sets of characteristics optimally fitting their different preferences.

9.3.5 Methods where the prices are based on revealed expenditures in related goods and services

9.44 Where prices for ecosystem services cannot be estimated using the methods described above, it is possible to use data about revealed expenditures in related goods and services, commonly referred to as cost-based methods.

9.45 **Averting behaviour method.** The averting behaviour method assumes that individuals and communities spend money on preventing or mitigating the negative effects and damages caused by adverse environmental impacts. The revealed expenditure demonstrates the value placed on the associated ecosystem services. This is the case, for example, in relation to incurring costs associated with extra filtration for purifying polluted water, air conditioning for avoiding polluted air, and so forth.

9.46 The actual expenditures incurred are considered a lower bound estimate of the benefits of mitigation, since it can be assumed that the benefits derived from avoiding damages are at least equal to the share of costs incurred to avoid them. An advantage of this method is that it is easier to estimate the expenses incurred than to estimate the avoided environmental damage. A disadvantage is that the expenditures may not be very sensitive to the differences in environmental quality, so they are not spatially sensitive in the way damage functions could be. Also, care is needed (i) to align the expenditure to specific ecosystem services since they may reflect securing a bundling of services; and (ii) to ensure that the expenditures reflect only the cost of avoiding environmental impacts rather than also reflecting matters of taste and consumption preferences.

9.47 **Travel cost method.** The travel cost method (TCM) is commonly used in economics to estimate the value of recreational areas based on the revealed preferences of visitors to the site. A demand function for recreation is estimated by observing the actual number of trips that take place at different costs of travelling to a recreational or cultural site and assuming that people hold similar preferences with respect to visiting the site. Costs of travelling include data on the expenditures incurred by households or individuals to reach a recreational site, entrance fees and may include the opportunity cost of time to travel and visit the site. Travel cost data are ideally captured at a detailed level that considers the different features of the sites being visited and enjoyed. The area under the demand function provides a measure of the welfare value of the site, i.e., including consumer surplus.

9.48 For ecosystem accounting purposes, it is required to calculate the exchange value of the associated ecosystem services, generally recreation-related services. An exchange value can be estimated on the basis of the demand function using the simulated exchange value method described below. In the absence of estimated demand functions, exchange values can be

[96] Triplett (2006) may be consulted for advice on the use of hedonic pricing approaches in a statistical context.

approximated based on aggregated travel cost data (e.g., fuel). Where travel cost data are not available, an alternative method to obtain the exchange value of recreation related services is to sum relevant consumption expenditures (e.g., using data from tourism satellite accounts).

9.3.6 *Methods where the prices are based on expected expenditures or markets*

9.49 The final group of valuation methods that are available for accounting purposes are those based on estimating the expenditures that would be expected to be made if the ecosystem service was no longer provided or was, in fact, sold on a market. Applying these methods is based on the logic that a loss of the ecosystem services would directly increase monetary costs (or reduce incomes) for economic units and that the presence of a market would reveal these effects.

9.50 **Replacement cost.** The replacement cost method estimates the cost of replacing the ecosystem service by something that provides the same contribution to benefits. It is also known as the substitute cost or alternative cost approach. The substitutes can be either a consumption item (e.g., an air filtration unit for a household substituting for air filtration services of trees) or an input factor (e.g., sorghum substituting for non-priced forage in the case of a rangeland grazing ecosystem services) or a capital factor (e.g., water treatment plant). In all cases, if the substitute provides an identical contribution, the price of the ecosystem service is the cost of using the substitute to provide the same benefits as provided by a single quantity unit of the ecosystem service (e.g., price for a tonne of forage). If applied in a single context (e.g., for a single farm), a direct accounting entry may be estimated based on the total cost of using the substitute in that context.

9.51 The validity of the replacement cost method depends upon three conditions being maintained: (i) the substitute can provide exactly the same function as the ecosystem service being substituted for; (ii) the substitute used is the least-cost alternative; and (iii) there is a willingness to pay for the substitute if the ecosystem service were to be no longer supplied. Thus, in the example of the non-priced forage noted above, it should be evident that the sorghum is a good substitute for rangeland fodder, that it is cheaper than other substitutes (e.g., moving livestock elsewhere, using other types of fodder), and that livestock operations would be continued if the rangeland grazing activity was curtailed.

9.52 **Avoided damage costs.** The avoided damage costs method estimates the value of ecosystem services based on the costs of the damages that would occur due to the loss of these services. Similar to replacement costs, the focus will generally be on services provided by ecosystems that are lost if the ecosystem were not present or was in sufficiently poor condition such that the services were not available. To obtain values and prices for accounting purposes, damages should be estimated using prices that are consistent with the exchange value concept. The validity of the avoided damage cost method depends also on similar conditions noted above with respect to the replacement cost method. The avoided damage method is particularly useful for regulating services such as soil erosion control and flood control, air filtration, and global climate regulation services.

9.53 The estimation of avoided damage costs will identify certain economic units who would be anticipated to avoid the damage costs as a result of the supply of ecosystem services. For example, the value of air filtration services may be related to avoided health costs to governments. However, this should not be interpreted as meaning this unit is the user of the service, it is solely a means to estimate the value of the service.

9.54 In some contexts, prices based on both replacement costs and avoided damage costs may be able to be estimated. If this is possible, the lower of the two estimated prices should be used. In most contexts, this would be expected to be the prices from the replacement costs method.

9.55 **Simulated Exchange Value (SEV) method**.[97] The simulated exchange value method estimates the price and the quantity that would prevail if the ecosystem service were to be traded in a hypothetical market. It thus provides a direct estimate of the value, the SEV, required for entry into the accounts based on the exchange value concept.[98] The SEV method is applied by using results from demand functions for the relevant ecosystem service (for example estimated using the travel cost method, discussed above, or stated preference methods, discussed below). These are used to calculate the price for the ecosystem service that would occur if it was actually marketed. This requires combining the information on the demand function with a supply function and an appropriate market structure (institutional context). Standard microeconomic methods are then used to yield the simulated price, which can be used to estimate the value of the ecosystem services. It can be applied at various degrees of complexity and using alternative market structures, but it has not been as widely applied as the methods described above.

9.3.7 Other valuation methods

9.56 There is a range of other valuation methods that are found in the environmental economics and ecosystem services valuation literature. These methods should not be applied in preference for any of the types of methods described above. If data based on these other methods are considered for compilation purposes, then they should be checked for consistency with exchange value principles and adjusted as required before use in the accounts.

9.57 **Shadow project cost**. This is a variant of the replacement cost method focussing on the hypothetical costs of providing the same ecosystem service elsewhere. It is less suitable for the valuation of individual ecosystem services since it is not intended to capture individual flows. Possible alternatives for the design of a shadow project include: asset reconstruction (e.g., providing an alternative habitat site for threatened wildlife); asset transplantation (e.g., moving the existing habitat to a new site); and asset restoration (e.g., enhancing an existing degraded habitat). The three conditions noted above for the replacement cost method apply to this method also noting that the method is only valid if the shadow project is actually realized or is planned to be realized.

9.58 This method is also linked to the restoration cost method which may be applied to value ecosystem degradation by estimating the costs that would need to be incurred to restore an ecosystem to its condition at the beginning of the accounting period. The restoration cost method is discussed further in chapter 12.

9.59 **Opportunity costs of alternative uses**. This approach estimates values of ecosystem services by measuring the forgone benefits of not using the same ecosystem asset for alternative uses. For example, the value of ecosystem services arising from not harvesting trees for timber (e.g., to supply global climate regulation services) can be measured by using the forgone income from selling timber. Thus, this approach measures what has to be given up for the sake of securing the ecosystem services. The opportunity cost approach is most useful when

[97] Based on Caparrós et al. (2017).

[98] Where the simulated quantity differs from the observed quantity (e.g. in terms of the number of visits), simulated price can be adjusted in a subsequent step such that the simulated exchange value is unchanged.

considering the ecosystem services that can be linked to certain purposes such as the protection of habitats, cultural or historical sites. The values obtained can be considered exchange values provided that (i) the valuation of the forgone benefits is based on exchange values; and (ii) the institutional context considered is sufficiently realistic such that the alternative scenario can be analysed. A primary difficulty with the opportunity costs approach is determining a realistic alternative use, since depending on the choice made, the value of the foregone benefits could vary substantially.

9.60 **Stated preference methods**. Stated preference methods do not utilize information on the behaviour of people in existing markets but rather use information from questionnaires to elicit likely responses of people by asking them to state their preferences in hypothetical situations. Stated preference methods do not directly reveal exchange values and hence require adjustment for use in accounting. These are the primary methods for estimating non-use values and hence may be relevant in some applications described in chapter 12. Stated preference methods fall into two broad types: contingent valuation and choice experiments.[99]

9.61 The contingent valuation method is a survey-based stated preference technique that elicits people's behaviour in constructed markets. In a contingent valuation questionnaire, a hypothetical market is described where the good in question can be traded. This contingent market defines the good itself, the institutional context in which it would be provided, and the way it would be financed. Respondents are asked about their willingness to pay for, or willingness to accept, a hypothetical change in the level of provision of the good, usually by asking them if they would accept a particular scenario. Respondents are assumed to behave as though they were in a real market (OECD, 2018).

9.62 Choice experiments are those where an individual is offered a set of alternative levels of supply of goods or services (typically two or three), in which the characteristics vary according to defined dimensions of quality and cost. By analyzing preferences across these different bundles of characteristics, it is possible to obtain the value placed by the individuals on each of the characteristics, provided (i) the bundles include a cost variable; and (ii) a baseline bundle is included that represents the status quo.

9.63 The information obtained from contingent valuation methods and choice experiments is the willingness to pay (WTP) for an ecosystem service or willingness to accept (WTA) payment for its loss. This information is then used to assess changes in consumer and producer surplus and, as such, does not provide an estimate of the value required for accounting purposes. However, by combining information on WTP or WTA of a range of recipients of the service, it is possible to derive a demand function for the ecosystem service and such a demand function may subsequently be used to derive an exchange value using an SEV approach.

9.64 **Prices from economic modelling**. Conceptually, it is possible to derive prices for ecosystem services from economic models that encompass relevant information on environmental and economic variables. For example, ecosystem services prices (e.g., for biomass provisioning services) may be elicited from computable general equilibrium models which take into consideration a wide range of factors and connections among economic sectors and which can be extended to include environmental factors. While potentially providing prices generated in more dynamic market contexts, the data requirements of applying these methods indicates that they are not likely to be suitable for use in ecosystem accounting.

9.65 **Qualitative methods**. There is a range of qualitative methods, including deliberative and group methods, that can be used in assessing the value of ecosystem services. However, since

[99] The pros and cons of different specifications are discussed in various publications; in particular, see Johnston, Boyle, et al. (2017) for state of the art guidance on stated preference methods.

these methods are generally not designed for the derivation of monetary values they are not considered appropriate for use in ecosystem accounting.

9.4 Valuation methods for different ecosystem services

9.4.1 Introduction

9.66 For the compilation of the ecosystem services flow account in monetary terms, the different valuation methods described in section 9.3 must be applied to individual ecosystem services. Compilers should apply the preference ordering for valuation methods outlined in section 9.3.1 when determining which valuation method to apply for a given ecosystem service. In practice, the method that is applied will often depend on data availability. The following sub-section provides general guidance on the issues to be considered in undertaking monetary valuation of different services. More detailed technical guidance for the implementation of valuation methods for individual services will be available in the forthcoming *Guidelines on Valuation of Ecosystem Services and Ecosystem Assets* (UNSD, n.d.-b, forthcoming).

9.4.2 Valuation of different types of services

9.67 Provisioning services include living resources harvested from unmanaged terrestrial and aquatic natural systems (uncultivated biomass) to highly managed plantations, aquaculture and livestock systems (cultivated biomass). The valuation of provisioning services should deal only with estimating the value related to the physical flows (e.g., fish) that are harvested for non-recreational, consumptive use, commonly as inputs to wider supply chains. The relevant measurement boundaries for provisioning services are described in chapter 6.

9.68 All biomass harvested is within scope of the production boundary of the SNA and hence exchange values for the relevant products are included in current measures of economic production. The valuation of ecosystem services is therefore focused on identifying the contribution of the ecosystem to the biomass product values which are themselves based on data on quantities traded, market prices and input costs.

9.69 In a number of situations, there may be significant flows of ecosystem services associated with subsistence agriculture, forestry and fisheries, that is, when the outputs from growing and harvesting activities are not sold on markets but directly consumed by households. A broad range of products may be relevant in this regard, including all types of non-timber forest products. Following the conceptual scope of the SNA, the production associated with these activities should be included in the national accounts estimates of output, with exchange values estimated on the basis of the prices of similar goods sold on markets.[100] There will then be an associated ecosystem services contribution to the recorded output. The methods described above for estimating the value of biomass provisioning services can be used for the valuation of the ecosystem services associated with subsistence production and consumption on the basis of these estimated market prices.

9.70 There is a wide range of regulating and maintenance services. In some cases, the contribution of these services is an input to SNA benefits. For example, the service of soil erosion control may be an input to agricultural production. In other cases, the services are contributions to non-SNA benefits, especially concerning improvements in human health, e.g., water purification services. In all cases, there are few, if any, distinct markets for the services and

[100] The handbook on measuring the non-observed economy (OECD et al., 2002) provides guidance on measurement approaches in this area.

identifying their relative contribution within existing market prices is likely to be challenging. Finally, most regulating and maintenance services exhibit considerable variation in their supply depending on local contexts and hence the measurement of the flows in biophysical terms will generally require biophysical modelling at relatively fine spatial scales.

9.71 Cost-based methods, such as the averting behaviour, replacement cost or the avoided damages methods, are the most commonly used methods for monetary valuation of regulating and maintenance services. In some cases, these services can be valued based on observed market transactions, such as in using data from payments for ecosystem services schemes or emissions trading schemes. However, there will be limits as to where these methods can be used to estimate exchange values depending on the institutional arrangements involved or the way in which services are quantified within the schemes (e.g., often management actions are used as a proxy for quantities).

9.72 For some services, especially those related to mitigating the effects of extreme events, the flow of the service will depend on the likelihood of events, both natural and related to human activity. For example, in measuring coastal protection services, there needs to be a likelihood greater than zero that events that may cause damage occur (e.g., tidal surge). The role of the ecosystem can then be assessed in terms of the extent to which it reduces the impact of such events. It is also necessary to consider the likelihood of damage. Thus, even if an event is likely, the ecosystem service flow will be lower if there is little damage expected. At the extreme, if there is no expected damage, then there is no user of a mitigation service and hence there is no flow of ecosystem services to be recorded. Overall, the likelihood of occurrence, the potential of damage, and the extent to which the relevant ecosystems can reduce these damages, will affect the value of the service.

9.73 For cultural services, generally, it is necessary to consider their monetary valuation from a demand or consumption perspective. The most common methods for recreation-related services are revealed preference methods based on the travel cost method, including payments for entry or related services. Methods for estimating the value of other cultural services include hedonic pricing where, for example the value of visual amenity services and local recreation services may be determined from the assessment of local house prices.

9.74 Using residual value approaches, it is possible to estimate the value of ecosystem services as inputs to the businesses involved in facilitating people's interactions with nature, for example island resorts or canoe hiring firms. In line with the recording in chapter 7, the flow of cultural ecosystem services are recorded as used by households and the value of any ecosystem services that may be a part of monetary payments to businesses are recorded as supplementary items in the supply and use table.

9.5 Spatial variation in values and value transfer for the purpose of ecosystem accounting

9.5.1 Introduction

9.75 Most commonly, the valuation of ecosystem services requires recognition that there will be variation in their values depending on the location and context in which the ecosystem services are supplied and used. The variation in ecosystem service values between locations occurs for a number of reasons. For example, the physical level of service provision may vary spatially such as when the global climate regulation service supplied through carbon sequestration by a forest varies from one side of a hill to another as solar energy varies with the aspect of that hill. Similarly, the recreation-related services supplied by a lake or river may vary depending on proximity to human populations; a lake near to a town may generate large recreational benefits while an ecologically identical lake located in a remote area might never be visited from one year to the next. Indeed, 'distance decay' in values over space is one of the most persistent and substantial determinants of ecosystem service valuation (Badura, Ferrini, Burton, et al., 2020; Johnston et al., 2019). In addition, there are likely to be differences in access and property rights (institutional context) in different locations. As a final example, the value of an ecosystem service may also vary due to underlying preference heterogeneity that occurs over space; i.e., human populations in some areas may simply have different preferences than populations living in other areas. Overall, failure to account for the influence of location will frequently lead to significant error (Bateman et al., 2006).

9.76 Generally, the discussion of monetary valuation for ecosystem accounting is focused on the compilation of estimates in monetary exchange value terms for large regions or countries with the expectation that these values can support the development, implementation and/or monitoring of public policy. In contrast, much work on valuation has used economic welfare values and has focused on the valuation of ecosystems and ecosystem services for specific ecosystems or in relation to the potential effects of policies and programs, such as the introduction of a new tax or subsidy, or in relation to hypothetical events, for example the valuation of damages caused by oil spills or the effects of ecosystem restoration. Consequently, much data on the monetary value of ecosystem services is fragmented, covering only specific services over a large area, or multiple services in a more confined area, or valuing changes in the flow of ecosystem services following a specific event.

9.77 Among the challenges for ecosystem accounting is how to reconcile and apply the information from existing studies to provide valid estimates of exchange value that may be applied consistently over large accounting areas, and that account for potential variations in ecosystem service values that occur over these areas. Indeed, while the consideration of larger areas might be thought to reduce error, this is not necessarily correct if the averages estimated for such areas are calculated in ignorance of spatial variation. The extent to which spatial variation in values can be accounted for will depend on data availability and the methodological considerations introduced here. If spatial variation in values cannot be adequately taken into consideration, then some applications of accounting data may not be appropriate.

9.78 Generally, there is a requirement for the ongoing expansion of work on estimating spatially explicit primary valuations to support the regular compilation of accounts. This is especially the case in order to minimise the use of primary data from other countries that have significantly different economic and institutional contexts. Although not discussed in this section, there is also a need to recognise that many primary valuations will not have been conducted with the intent to estimate exchange values as used in ecosystem accounting. The use of primary valuations will therefore need to consider the differences in valuation techniques and relevant assumptions described in section 9.3 to ensure that the estimates are fit for accounting purposes.

9.79 This section provides a short overview of the relevant considerations and potential measurement approaches for ecosystem accounting concerning the spatial variation in values. A key message is that there is an extensive body of research and applied practice that can be used. At the same time, considering the issues from an ecosystem accounting perspective, highlights areas where further research will be required including concerning exchange values and marketed ecosystem services. More detailed discussion of relevant methods is available in technical guidance on valuation for ecosystem accounting.

9.5.2 Methods for incorporating spatial variation in prices

9.80 To utilize data from specific locations in the estimation of monetary values in other locations, a set of techniques can be applied, collectively referred to as value transfer or benefit transfer techniques.[101] There are two main approaches to value transfer: unit value transfers and value function transfers. Value function transfers may be further disaggregated into subgroups, including 'meta-analysis' function transfers and other types value function transfers (Johnston et al., 2015, Chapter 2). These techniques have been developed over many decades in the environmental economics community. Boyle et al. (2010), Johnston et al. (n.d., 2018) and Johnston & Rosenberger (2010) provide reviews of the relevant literature.

9.81 A **unit value transfer** takes a single estimate of the monetary value of an ecosystem service (expressed in terms of a common measurement unit, e.g., hectare, tonnes, visits), or a measure of central tendency (e.g., mean, median) of several value estimates from different studies, to estimate the value of an ecosystem service in other locations. The validity of a unit value transfer approach will be limited when there is a range of differences between the value from the observed location and the other locations. Unit value transfers typically provide little or no internal capacity to account for these differences. Examples of the differences that can cause values to differ across locations can include:

- The physical characteristics of the sites that generates variation in the ecosystem services that the location provides such as, in the case of a lake, differing opportunities for recreation in general and angling in particular.
- The socio-economic and demographic characteristics of the relevant populations in the different locations. This might include income, educational attainment and age.
- The variation in the preferences of populations across different locations.
- The variation in institutional context governing rights of access to, use of and duties towards biodiversity, ecosystems and their services.
- The distance between the user of the ecosystem service and the supplying ecosystem asset, along with other geospatial differences that influence values in systematic ways (Glenk et al., 2020). Note also that the effect of distance will vary depending on the ecosystem service, for example the benefits of the global climate regulation service emerge irrespective of distance, whereas the benefits from water purification services arise only to people located close to (or downstream of) the supplying ecosystem.
- The variation in the availability of substitutes and complements. For example, in the case of recreational locations such as lakes. Two otherwise identical lakes might be characterised by different levels of alternative recreational opportunities. Other things being equal (by assumption in this example), the value of preventing a lowering of water quality at a lake where there are few substitutes should be greater than the value of avoiding the same water quality loss at a lake where there is an abundance of recreational substitutes. The reason for this is that the former is a scarcer recreational location than the latter.
- Differences across countries reflected in spatial and temporal variation in purchasing power.

9.82 Failure to adjust for location specific conditions affecting exchange value means that applying the unit value transfer approach works as a simple scaling factor for the changes observed in

[101] While much of the literature in this area uses the term benefit transfer, the term value transfer is preferred here, recognising the focus on estimating exchange values and the distinct use of the term benefit in the ecosystem accounting framework (see Chapter 6).

the physical supply and use table. Thus, an unadjusted unit value provides no additional information when reflected in a monetary supply and use table. Such linear monetary scaling may still be useful for compiling the monetary asset account for purposes that require only low accuracy, but care should be made to identify generalization errors and confidence ranges.

9.83 Since differences between locations such as those just listed will exist, adjustments are generally made to take the differences between locations into account. In the first instance adjustments may be made to account for income per capita and income elasticities to derive an **adjusted unit value transfer**. Meta-studies (such as OECD (2014)) indicate that adjusting for income per capita is a significant factor in being able to apply values from one location to others. This adjustment is likely to be of most significance if using primary data from another country. While data from other countries may be used in compiling accounts, it is advisable to use primary data from the country for which the accounts are being compiled wherever possible.

9.84 A more sophisticated form of value transfer is to undertake a **value function transfer**. These transfers can be categorized in different ways. Here, we group them into four primary categories based on the way the value functions are estimated. The first type estimates a value function using meta-analysis of prior valuation studies. The second type estimates a function concerning the relationship between value and the ecosystem and economic context from a primary research study in one location and uses that function in other locations. The third type uses primary data from multiple locations across a region to generate an “umbrella” function that can be applied to other locations within the region (see for example, Bateman et al. (2013)). This approach has the advantage of using data sets that encompass both the location of the primary data site/s and the transfer site/s thus avoiding “out of sample” problems. This approach may also be referred to as value generalisation. The fourth type is known as structural value transfer (also called preference calibration). This type of transfer combines information from multiple prior primary studies using a utility theoretic structure that is assumed to apply to the prior studies. These different types of value function may encompass factors such as the physical features of the location, changes in population age structure between sites and differences in population density.

9.85 When used for value function transfer, **meta-analysis**, e.g., Bateman et al. (2000) and Boyle & Wooldridge (2018), takes information from a range of existing primary studies and then estimates a functional relationship that enables the values of ecosystem services to be predicted as a function of, *inter alia*, site and spatial characteristics, attributes and size of population affected, and the type of statistical methods 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.

9.86 This approach is well suited to developing estimates for additional sites and can be used to provide estimates at larger scales, including at the national level (see for example, Corona et al. (2020) and Johnston et al. (2019)). Application of meta-analysis to the field of non-market valuation has expanded rapidly in recent years. Studies have taken place in respect of water quality, urban pollution, recreation, the ecological functions of wetlands, values of statistical life, noise and congestion.

9.87 At the same time, meta-analysis will sometimes use data from a variety of countries and variations between countries will need to be recognised. As well, it will be necessary to appropriately identify and select the studies to be used in the meta-analysis to ensure, for example, welfare consistency and commodity consistency (Johnston et al., 2018). Guidelines for the selection and coding of studies for economic meta-analysis are also available (see for example Stanley et al. (2013)). Meta-analytic transfers using valuation studies from other countries outside the ecosystem accounting area should take care to adjust for particular differences in national jurisdiction affecting access and use rights.

9.88 The extent to which different value transfer methods can capture spatial variations in value and their general accuracy has been one area of extensive research. See for example, Bateman et al. (2006), Johnston et al. (2019), Johnston, Besedin, et al. (2017) and Schaafsma (2015) for discussions and a review of relevant work. Further, guidelines are being developed focused to more broadly improve the quality of estimates derived through the use of value transfer techniques (see Johnston et al. (n.d. and 2020)). Fundamentally, the quality of value transfer approaches will be influenced by the number, depth (in terms of number of data points) and quality of spatially explicit primary valuation studies. In turn this will likely depend on the type of ecosystem and the type of ecosystem service being considered. For example, while there are many studies of recreational use of ecosystems, there are not as many studies on the value of wetlands. Since different valuation studies are also often based on different assumptions, different valuation concepts and use different methods, there is a strong case for using the SEEA EA framework and its application through the practice of official statistics to develop consistently measured values across a variety of ecosystem services and locations. In developing these studies, co-ordination with the organisation of data in physical terms on ecosystem extent, condition and ecosystem service flows is highly recommended since this data will assist in consistently differentiating and classifying these data spatially and in ensuring consistent appreciation of the supply and use context for the ecosystem services.

9.89 When considering the direct applicability of existing value transfer research and findings to environmental accounting, it is important to consider the extent to which the types of values considered within the value transfer literature are consistent with those used within accounting applications. For example, much (although not all) of the available value transfer literature is based on stated preference methods. Stated preference methods establish hypothetical markets to quantify welfare values of changes in non-marketed ecosystem condition and/or services. For accounting purposes, it is necessary to simulate exchange values by combining these stated preference functions with ecosystem service supply/cost functions. Simulating exchange values therefore require the definition of credible institutional conditions for a market for the ecosystem in question (Barton et al., 2019). Institutional regimes are specific to ecosystems and resource characteristics (Ostrom, 2010). Accounting principles state that accounting compatible prices should reflect current or feasible market institutions. Compilers should therefore recognize that transferring or generalizing valuation estimates from actual or hypothetical markets, to locations without markets, may potentially contradict national accounting principles. In particular, care should be taken where market simulation contradicts existing rights regimes. In these situations, simulated exchange values, and monetary accounts more generally, may be perceived as invalid by local rights holders. This is a particular issue in ecosystems with open access or common property rights (e.g., community fisheries and forests, communal greenspace).

9.90 The conceptual ideal of location-based valuation of all ecosystem services is clear. While this has been rarely possible due to resource constraints, rapid increases in the availability of spatial data and the ongoing advances in valuation methodologies will make this more possible in the future. As introduced in this section, there are well-researched value transfer techniques available for use in ecosystem accounting that can utilise available primary valuation studies. Further testing and best practice guidelines in defining credible market exchange conditions for value transfers should be part of the SEEA EA research agenda. To support appropriate use and interpretation of monetary estimates and to provide a sound basis for further research and development of data, clear documentation of the data sources, and the methods and assumptions applied in forming aggregate values for entry into the accounts will be required.

10 Accounting for ecosystem assets in monetary terms

10.1 Introduction

10.1 The series of ecosystem accounts is completed with the monetary ecosystem asset account. This account records a monetary value of ecosystem assets in terms of the net present value of the ecosystem services supplied by the asset. The estimates of monetary value are compiled following the net present value principles described in chapter 8 and using the exchange value concept. The estimates provide a measure of the exchange value related to the scope of ecosystem services recorded in the ecosystem services flow account and cannot be interpreted as reflecting a complete or universal measure of the value of nature.

10.2 The monetary ecosystem asset account also records the changes in the monetary value of ecosystem assets over an accounting period including changes due to ecosystem degradation, ecosystem enhancement, ecosystem conversions and revaluations.

10.3 Estimates of ecosystem assets in monetary terms can support discussion of the relative significance of different ecosystem assets and ecosystem types and the monetary value of ecosystem assets can be combined with the monetary valuations of other types of assets, for example produced assets, to provide broader assessments of net wealth, such as in wealth accounting.[102] Measures of ecosystem assets in monetary terms may also be related to general socio-economic drivers of change such as changes in economic activity and demographic trends. Together with information about the assets in physical terms (e.g., measures of ecosystem condition) they may be used as part of an assessment of the sustainability of the flows of ecosystem services. Further, because there is a focus on future flows of ecosystem services, measures of the value of ecosystem assets can support project design and monitoring requirements.

10.4 At the same time, as noted in chapter 8, measures in monetary terms on their own will not be sufficient for the analysis of non-marginal changes in ecosystems or issues of sustainability that concern ecological thresholds and boundaries. Consequently, there is significant advantage in using the ecosystem accounting system which provides a clear “line of sight” between the physical data on ecosystem extent and condition, measures of ecosystem service flows and ecosystem capacity, and monetary values. More generally, in analysing changes in value, there is the need to assess the effects of price change and to focus on the relevant changes in the volumes of assets and services.

10.5 Measures of ecosystem degradation in monetary terms will be of particular interest in understanding changes in ecosystem assets relative to measures of economic activity such as industry value added. The derivation of degradation adjusted income measures is explained in chapter 11, together with a description of extended balance sheets and extended institutional sector accounts.

10.6 Section 10.2 sets out the structure of the monetary ecosystem asset account and the associated accounting entries. Section 10.3 describes the key components in valuing ecosystem assets using the net present value approach including the approach to valuing the accounting entries for changes in ecosystem assets over an accounting period.

[102] See UNEP (2018) and World Bank (2018).

10.2 Monetary ecosystem asset account

10.2.1 Structure of the monetary ecosystem asset account

10.7 The monetary ecosystem asset account records the monetary values of all ecosystem assets within an ecosystem accounting area at the beginning (opening) and end (closing) of each accounting period; as well as changes in the value of those assets over the accounting period. Changes in the monetary value of ecosystem assets are separated into five broad types: ecosystem enhancement, ecosystem degradation, ecosystem conversions, other changes in the volume of ecosystem assets, and revaluations as a result of price changes.

10.8 The description provided in this section reflects a framing in which an individual ecosystem asset is able to be valued as a single entity reflecting the net present value of the set of ecosystem services it supplies as recorded in the ecosystem services flow accounts. Thus, the concepts concerning the change in value such as ecosystem degradation and ecosystem enhancement are defined by viewing the ecosystem asset as a single entity in line with the framing for the measurement of ecosystem extent and condition.

10.9 In practice, as explained in section 10.3, the value of an ecosystem asset is obtained by estimating the net present value of each ecosystem service supplied by an ecosystem asset separately and taking into consideration key linkages among services and assets to the extent possible. The approach to reconciling the ecosystem service specific NPV estimates and the changes in ecosystem asset values described in this section are explained in annex 10.1. This reconciliation approach is pragmatic and suitable for accounting purposes. Improvements to the approach may be found through additional modelling that considers in more depth the links between ecosystem condition, ecosystem capacity and ecosystem service flows but the accounting structure described in this section is unaffected.

10.10 The basic accounting structure for the monetary ecosystem asset account is shown in Table 10.1. This table shows an account for an ecosystem accounting area classified by ecosystem type using selected ecosystem functional groups from the IUCN GET (see chapter 3).

10.11 The opening and closing values are derived using the net present value of ecosystem services for the given ecosystem type based on the concepts described in chapter 8 and using the approach to estimating net present values described in section 10.3. Data on the monetary value of ecosystem services by ecosystem type comes from the ecosystem services flow account in monetary terms described in chapter 9. The opening and closing values are the first estimates compiled in compiling the monetary ecosystem asset account.

10.12 Entries for ecosystem degradation and enhancement involve assessing the change in net present value and comparing this to the change in condition for that ecosystem type as recorded in the ecosystem condition account described in chapter 5 and applying the definitions of ecosystem degradation and enhancement below. Entries for ecosystem conversions will build on entries recorded in the ecosystem extent account (chapter 4). The additions and reductions shown in that account in physical terms will align with the additions and reductions in monetary terms that are recorded under ecosystem conversions. Entries for other changes in the volume of ecosystem assets and revaluations will be based on specific information concerning those changes as described below. Annex 10.1 provides a worked example of how each of these accounting entries can be estimated to compile a monetary ecosystem asset account.

10.13 As required, and where data are available, asset accounts showing the same accounting entries can be compiled for individual ecosystem assets (e.g., a specific grassland), for all ecosystem assets of a single ecosystem type (e.g., all Trophic savannas (EFG T4.1)) or for various types of ecosystem accounting areas (e.g., a country, a large administrative area or a catchment) that include multiple ecosystem assets of different ecosystem types.

10.14 Depending on data availability it may be necessary to combine some accounting entries by netting the change in value. For example, net ecosystem conversions might be recorded rather than separately recording additions and reductions. Further, in many contexts, there may be multiple potential entries over an accounting period reflecting a combination of enhancement, degradation and other types of changes. This section outlines the conceptual ideal for distinguishing the various entries, recognising that making the distinctions in practice will commonly rely on the judgement of the compiler. At the same time, the measure of net change in ecosystem asset value should be well-bounded by measures of the opening and closing value and the various changes can also be linked to the measures in physical terms recorded in the ecosystem extent and condition accounts.

Table 10.1: Monetary ecosystem asset account (currency units)

	Ecosystem type (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																		
	Terrestrial												Freshwater			Marine			
	T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1	
	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	...	Temperate pyric sclerophyll forests and woodlands	...	...	...	Derived semi-natural pastures and old fields	Permanent upland streams	...	Intermittently closed and open lakes and lagoons	Seagrass meadows	...	Coastal saltmarshes and reedbeds	
	T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3	TOTAL
Opening value																			
Ecosystem enhancement																			
Ecosystem degradation																			
Ecosystem conversions																			
Additions																			
Reductions																			
Other changes in volume of ecosystem assets																			
Catastrophic losses																			
Reappraisals																			
Revaluations																			
Net change in value																			
Closing value																			

10.2.2 Ecosystem enhancement

10.15 ***Ecosystem enhancement is the increase in the value of an ecosystem asset over an accounting period that is associated with an improvement in the condition of the ecosystem asset during that accounting period***. The increase in value will be demonstrated by a rise in the net present value of expected future returns of the ecosystem services supplied by that asset. Ecosystem enhancement will incorporate the effects of activities, including those related to a reduction in harmful activities, that have improved the condition of an ecosystem asset beyond activities that may simply maintain an ecosystem asset's condition. Ecosystem enhancement may also arise as the result of natural and unmanaged improvements in condition.[103] There will not be a linear relationship between changes in condition and future flows of ecosystem services.

10.16 Not all increases in value should be recorded as ecosystem enhancement. The focus should be on recording increases in asset value resulting from improvements in ecosystem condition that can be reasonably expected to increase the future flows of ecosystem services in physical terms, based on the current and expected patterns of ecosystem management and use. Increases in value attributable to changes in the expected demand for ecosystem services should be recorded as upward reappraisals. Increases in value due solely to movements in the unit prices of ecosystem services should be recorded as revaluations.

10.17 Ecosystem enhancement is measured in relation to the extent of an ecosystem asset as recorded at the beginning of the accounting period. Where there are changes in the extent of an ecosystem asset, that is where there is change (conversion) from one ecosystem type to another during an accounting period, a separate recording of that change should be undertaken, and recorded under the entry ecosystem conversions.

10.18 Three types of activities may be considered in the context of ecosystem enhancement: restoration, rehabilitation and reclamation. Each of these activities represents different degrees of expected effect on the ecosystems from the activity.[104] Restoration occurs where the aim is to re-establish pre-existing structure and function, including biotic integrity. Rehabilitation occurs where the aim is to reinstate ecosystem functionality with focus on supplying a range of ecosystem services. Both restoration and rehabilitation activities may be achieved by reducing the degree of human impact, for example by reducing stocking rates on grazing land, by reducing the release of pollutants, or by separating or re-zoning areas as being the focus of restoration and rehabilitation. Reclamation occurs where the aim is to return degraded land (e.g., loss of topsoil due to poor land management practices) to a useful state (e.g., for agriculture). Where restoration, rehabilitation or reclamation activities result in a change in ecosystem type during the accounting period, increases in value due to the activity should be recorded under ecosystem conversions.

10.19 Measures of ecosystem enhancement will be linked to activities undertaken in the landscape. Consequently, the recorded changes in extent, condition and ecosystem asset value can be compared to estimates of expenditure and other measures of human input (e.g., volunteer hours) associated with that activity. However, there are no prior expectations on the results of such a comparison. For example, it should not be expected that the changes in net present value of an ecosystem asset would be the same as the levels of expenditure on environmental protection or restoration activity. Thus, to support decision making and analysis, data on ecosystem enhancement may be presented to complement measures of expenditure and may provide an indication of the broader future returns that may arise in relation to a given level of expenditure.

10.20 In this context, there will be a connection to the measurement of land improvements as recorded as a component of gross fixed capital formation in the SNA, and to the measurement of environmental protection and resource management expenditure as recorded in the SEEA Central Framework. There may also be interest in comparing changes in ecosystem asset value associated with these environmental activities with data on the ownership of the ecosystem assets.

[103] In a SEEA Central Framework context this will relate to the concept of natural growth of biological resources.

[104] For details see the UNCCD Land Degradation Neutrality conceptual framework: https://www.unccd.int/actions/ldn-target-setting-programme.

10.2.3 Ecosystem degradation

10.21 ***Ecosystem degradation is the decrease in the value of an ecosystem asset over an accounting period that is associated with a decline in the condition of an ecosystem asset during that accounting period.*** The decrease in value will be demonstrated by a fall in the net present value of expected future returns of the ecosystem services supplied by that asset. Ecosystem degradation will arise as the result of both managed and unmanaged declines in condition.

10.22 Not all decreases in value should be recorded as ecosystem degradation. The focus should be on recording decreases in asset value resulting from declines in condition that can be reasonably expected to decrease the future flows of ecosystem services in physical terms, considering the current and expected patterns of ecosystem management and use, and expected patterns of environmental variation.

10.23 Declines in condition may arise from a range of sources including the extraction and harvest of natural resources and the short and long-term effects of pollution and emissions. Where there is harvesting or extraction of resources from an ecosystem (e.g., of fish resources or through grazing), the assessment of the decline in condition should be considered at an appropriate scale and over an appropriate time frame wherein the level of harvesting or extraction can be assessed relative to a rate of regeneration of the resource. Only extraction at rates above the rates of regeneration should contribute to degradation.[105]

10.24 Decreases in value due to large scale, discrete and recognisable events that cause a significant loss in the condition of an ecosystem asset should be recorded as catastrophic losses. Decreases in value attributable to changes in the expected demand for ecosystem services should be recorded as downward reappraisals. Decreases in value due solely to movements in the unit prices of ecosystem services should be recorded as revaluations.

10.25 Ecosystem degradation is measured in relation to the extent of an ecosystem asset recorded at the beginning of the accounting period. Where there are changes in the extent of an ecosystem asset, that is where there is change (conversion) from one ecosystem type to another during an accounting period, a separate recording of that change should be undertaken, and recorded under the entry ecosystem conversions.

10.26 In non-SEEA contexts, the scope of measures of ecosystem degradation may be broader than defined here. For example, the effects of some conversions, for example from natural to cultivated ecosystem types, may be incorporated in measures of degradation.

10.27 The measurement of ecosystem degradation reveals the loss of future flows of ecosystems services but will not capture wider economic and social impacts of declines in ecosystem condition that may also arise. For example, degradation of cultivated land may lead to losses of farm incomes and employment opportunities in rural communities. Similar observations apply to entries concerning ecosystem enhancement, ecosystem conversion and catastrophic losses. The analysis of these wider impacts can be supported by data from the ecosystem accounts, together with other data from, for example, the national accounts and labour force statistics.

10.28 The measurement of ecosystem degradation can be undertaken for an ecosystem asset without specific regard to the legal or economic ownership of the ecosystem asset. However, for some analytical purposes and for integration of ecosystem accounts into the general sequence of institutional sector accounts of the SNA, it is necessary to attribute the cost of ecosystem degradation to an economic unit and institutional sector. Approaches to the

[105] This treatment is consistent with the definition of depletion in the SEEA Central Framework.

attribution of ecosystem degradation to institutional sectors are discussed in chapters 11 and 12.

10.29 The SEEA Central Framework, section 5.4, defines the depletion of natural resources 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."* (SEEA Central Framework, para 5.76). This definition can be seen as sitting within the definition of ecosystem degradation to the extent that the quantity of a stock of a natural resource is considered part of the structure and composition of an ecosystem asset. The term depletion is retained to refer solely to the cost of using up natural resources. This measure will be narrower in scope than ecosystem degradation since it will only relate to the loss of future provisioning services. However, an economy-wide measure of depletion will be broader in scope to the extent that it includes declines in the net present value of the stock of non-renewable resources due to extraction, in particular mineral and energy resources, since these fall outside of the scope of ecosystem assets.

10.2.4 Ecosystem conversions

10.30 Ecosystem conversions refer to situations in which, for a given location, there is a change in ecosystem type involving a distinct and persistent change in the ecological structure, composition and function which, in turn, is reflected in the supply of a different set of ecosystem services and different expected future returns.

10.31 In physical terms, ecosystem conversions that occur during the accounting period should be recorded as changes in ecosystem extent, e.g., a change from shrubland to cropland, following the advice in chapter 4. An ecosystem conversion may commonly apply only to part of an existing ecosystem asset. In the ecosystem extent account, the increases in the area of one ecosystem type and decreases in another ecosystem type at a given location will net to zero.

10.32 Consistent with the definition of ecosystem degradation, the assessment of the change in ecosystem type should be undertaken at an appropriate scale and over an appropriate time frame to allow for assessing the effects of, for example, harvesting or extraction of natural resources, or forest fires, relative to rates of regeneration. More generally, it will be relevant to consider changes in ecosystem condition since these will provide an indicator of potential changes in ecosystem type.

10.33 In monetary terms, a decrease in value will be recorded for the ecosystem type which the area has been converted from (e.g., shrubland) and an increase in value will be recorded for the ecosystem type which the area has been converted to (e.g., cropland). Both of these entries should be recorded in the rows for ecosystem conversions as additions or reductions.

10.34 However, across an ecosystem accounting area, there is no expectation that the value of expected future returns for additions and reductions will be offsetting. Thus, the net effect in monetary terms of ecosystem conversions may be positive or negative depending on the differences in the set of expected ecosystem services that are generated by the different ecosystem types.

10.35 Depending on the data available, it may be of interest to present data on ecosystem conversions according to reasons for conversion including agricultural expansion, increased urbanisation, coastal mangrove destruction by hurricanes or reclamation of desert areas to become grazing land.

10.2.5 Other changes in the volume of ecosystem assets

10.36 Other changes in volume is an SNA-defined accounting entry that provides the opportunity to record all other changes in the value of an asset between balance sheet dates that are not attributable to transactions or revaluations (see 2008 SNA, chapter 12). In the context of ecosystem accounting, ***other changes in the volume of ecosystem assets are changes in the value of an ecosystem asset, other than (i) those due to ecosystem enhancement, ecosystem degradation and ecosystem conversion, and (ii) those that are solely the result of changes in unit prices of ecosystem services.*** The two main types of other changes in the volume of ecosystem assets are catastrophic losses and reappraisals.

10.37 Decreases in the value of ecosystem assets due to catastrophic losses are identified separately to provide scope for compilers to record decreases due to large scale, discrete and recognisable events that cause a significant decline in the condition of an ecosystem asset, i.e., significant losses in structure, function or composition, and hence affect the future flows of ecosystem services in physical terms. Examples include earthquakes, bushfires, cyclones and industrial disasters. While these events may be anticipated in general terms, the precise timing, location and magnitude cannot be foreseen in the same way as expectations may be formed about patterns of ecosystem use by people.[106] The effects on future flows of ecosystem services may be temporary if the ecosystem quickly recovers to its previous condition or permanent if the changes are such that some ecosystem services can no longer be supplied or accessed (e.g., due to changes in regulations). Where the effects of the large-scale events is significant enough such that it is considered that the ecosystem has changed ecosystem type, this should be recorded as an ecosystem conversion.

10.38 Reappraisals should be recorded when updated information emerges that permits a reassessment of the expected condition of the ecosystem assets or the future demand for ecosystem services, such that the expected pattern of future returns at the end of the accounting period is different from the pattern that had been expected at the start of the accounting period. For example, the effects of changes in demographic projections that affect the future demand for ecosystem services should be recorded as reappraisals; as well as changes in the future flows of services due to rezoning of land or changes in the risk of extreme events.

10.39 Reappraisals concern changes in expectations and are materially different from the use of updated information to improve the quality of compiled estimates. The incorporation of new information concerning expectations does not lead to revisions in previous estimates.

10.40 Where improved or revised source data are used (e.g., through the use of more detailed ecological information and biophysical modelling) or where revised methods and classifications are adopted, the changes should be applied consistently across all relevant accounting entries and, as appropriate, revisions to past accounting entries should be made. A separate accounting entry to distinguish revisions due to changes in source data is not required but for data quality assessment purposes documenting all revisions to accounts is strongly recommended.

10.2.6 Revaluations

10.41 ***Revaluations are changes in the value of ecosystem assets over an accounting period that are due solely to movements in the unit prices of ecosystem services which underpin the derivation of the net present value of ecosystem assets.*** Following the SEEA Central

[106] See also 2008 SNA, paras. 12.46 & 47 and SEEA Central Framework, para. 5.49.

Framework (para. 5.61), a change in the value of an ecosystem asset in response to a change in the quantity or quality of future flows of ecosystem services is not considered a revaluation and should be recorded, as appropriate as ecosystem enhancement, ecosystem degradation, ecosystem conversion or other changes in volume.

10.42 Revaluations reflect nominal holding gains over an accounting period and there may be analytical interest in decomposing these gains into the neutral holding gain – equivalent to the nominal gains associated with the general rate of inflation – and real holding gains. Holding gains may be positive or negative since the nominal gains may be greater or less than the general rate of inflation.

10.43 Revaluations should also incorporate changes in the value of ecosystem assets due to changes in the assumptions made in the parameters that are used to estimate net present values, such as the discount rate, to the extent that these effects can be isolated. Changes in estimated values that are due to changes in methods are treated as revisions.

10.3 Approaches to valuing ecosystem assets

10.3.1 General approach to valuing ecosystem assets

10.44 The net present value (NPV) approach to the valuation of ecosystem assets was introduced in chapter 8. In mathematical terms, the value V_t of a single ecosystem asset at the end of an accounting period t is written as:

$$V_t(\boldsymbol{EA}) = \sum_{i=1}^{i=S} \sum_{j=t+1}^{j=t+N} \frac{ES_t^{ij}(\boldsymbol{EA}_t)}{(1+r_j)^{(j-t)}}$$

where ES_t^{ij} is the value of ecosystem service i in year *j* as expected in period t (e.g., 2020) generated by a specific ecosystem asset $\boldsymbol{EA}_t$; S is the total number of ecosystem services; r_j is the discount rate (in year *j*), and *N* is the lifetime of the asset, which may be infinite for some ecosystem assets if used sustainably.[107]

10.45 In ecosystem accounting, an ecosystem asset generates a bundle of ecosystem services, each valued separately. The NPV formula is applied at the level of individual ecosystem services and the resulting discounted values are aggregated to derive the monetary value of the ecosystem asset. Where the ecosystem service values are based on observed market prices for associated benefits (e.g., in the resource rent method), the costs incurred in supplying the ecosystem services will be excluded such that the value used considers only the contribution of the ecosystem. A discussion on the various components of the equation is presented in the following sub-sections.

10.46 Each ecosystem service is considered separable in the sense of each ecosystem service (i) being able to be measured distinctly, i.e., in a mutually exclusive manner; and (ii) representing a distinct flow between an ecosystem asset and a user. At the same time, in measuring the NPV for each ecosystem service, it is necessary to recognise that while each ecosystem service is generated from an ecosystem asset, different characteristics of that ecosystem asset will be relevant in the generation of each service. Thus, in this formulation, while there is a common location there is not a single distinct stock, in the sense usually applied in for example, using

[107] The assumption made here is that the returns accrue at the end of the accounting period and hence the first future period's flows (e.g., 2021) are discounted. This assumption is used to simplify the explanation and the associated notation but has no impact on the underlying relationships described.

NPV to value mineral and energy resources or timber resources as in the SEEA Central Framework.

10.47 Consequently, while each ecosystem service flow and its associated NPV is considered separable, it is necessary that the inherent connections among ecosystem characteristics within an ecosystem asset in a given location are jointly considered when determining the expected future returns of each ecosystem service. General proposals for providing a reasonable baseline for consistency in measurement are set out below with the general aim of avoiding contradictions within a set of accounts. This ambition provides a suitable basis for meaningful interpretation for monitoring and decision making.[108]

10.48 Assuming that the expected future returns for each service are estimated based on the exchange value concept, the NPV for an ecosystem service will provide an exchange value for the capitalised value of that service, and the aggregate NPV will provide an exchange value for the ecosystem asset. In order to decompose the change in asset value from the beginning to the end of an accounting period, for example to record the value of ecosystem degradation, the changes in price and quantity of future returns for each ecosystem service are analysed. Annex 10.1 provides a description of the decomposition approach.

10.49 The general principles just outlined apply to the situation where ecosystem services are attributable to individual ecosystem assets. Commonly, the measurement and valuation of ecosystem services is undertaken using detailed spatial data which in turns supports the potential to undertake measurement at this level of detail. The spatial attribution of ecosystem services to different ecosystem assets is discussed in chapter 7. Where ecosystem services are not attributed to a single ecosystem asset, it remains possible to estimate the NPV of each ecosystem service and aggregate to determine a total value of ecosystem assets for an EAA. Further, in practice, it may be necessary to undertake projections at a more aggregated scale (e.g., with respect to demography) rather than for individual ecosystem assets. Nonetheless, where possible, estimation should be undertaken for smaller, sub-EAA spatial areas to assist in recognising variations in local contexts, including differences in ecosystem characteristics and in institutional arrangements (see also section 10.3.6).

10.50 As introduced in section 8.2, the measurement of expected future returns involves consideration of five key aspects: (i) the scope and definition of returns; (ii) the valuation of returns; (iii) future flows of ecosystem services in physical terms; (iv) asset lives; and (v) expected institutional arrangements. Each of these aspects is considered in more detail in the following sub-sections. In practice, all aspects will be connected and an iterative process will be needed to establish a clear and agreed basis for estimating expected future returns across multiple ecosystem services. Importantly, the integrated approach used in ecosystem accounting, especially the use of consistent classes of ecosystem types to underpin the organisation of relevant data, provides the structure within which all of the relevant aspects can be consistently approached.

10.51 In addition to estimating expected future returns, the second key component is the discounting of these returns to their present value. Mathematically, this is a straightforward calculation but the selection of an appropriate discount rate is a matter of considerable importance since it can have a significant effect on the resulting asset value and on its interpretation. The selection of discount rates is discussed in section 10.3.7.

[108] It will likely be possible with advances in biophysical science, and associated economic modelling, to better estimate expected interactions within ecosystems with respect to the supply of ecosystem services. Indeed, advances in this direction are occurring and an important area of future research will be connecting these advances to the task of improving the valuation of ecosystem assets. See for example Fenichel et al. (2018).

10.52 To support the interpretation of estimates and comparison of results from different sets of accounts, it is necessary that all assumptions used to underpin the measures of the value of ecosystem assets and changes in value are clearly documented.

10.53 It is standard practice to record single, point estimates in the accounts. However, given the assumptions required to underpin valuation in monetary terms, it may be appropriate to provide a range of values that could be obtained under plausible alternative assumptions. For example, estimates of the value of ecosystem assets might be provided using different assumptions concerning the discount rate.

10.54 The description of the NPV approach in this chapter is aligned with the discussion in the SNA and the SEEA Central Framework. The key difference in application concerns the need to aggregate multiple future returns for a single asset value. The alignment in approach supports the compilation of extended balance sheets that incorporate ecosystem assets alongside other asset classes (see chapter 11). Because the approach described here involves the aggregation of individual ecosystem services, it should be possible to integrate directly estimates from the SEEA Central Framework for natural resources provided they can be matched to the relevant provisioning service and ecosystem asset. This also means that alternative valuations for those services can be incorporated, potentially using directly observed data (for example on land values) or variations on the NPV formulation above such as the stumpage method for valuing timber resources.[109]

10.3.2 Scope and definition of returns

10.55 The scope of returns concerns the set of ecosystem services that is included in the valuation for any given ecosystem asset. In practice, the set of ecosystem services included for asset valuation should align with the set of services recorded in the monetary ecosystem services flow account for each ecosystem type, as recorded in Table 9.1, in turn building on the measurement of ecosystem services in physical terms as described in chapters 6 and 7. Compilers should include a comprehensive range of ecosystem services in order to best reflect the monetary value of the asset and its changes over time.

10.56 The returns included in the net present value calculation refer to the ecosystem services expected to be supplied by an ecosystem asset. As described in chapter 8, ecosystem services are the contributions of ecosystem assets to benefits and hence ecosystem services and benefits must be clearly distinguished. By way of example, in the case of timber provisioning services, the ecosystem services will refer to the contribution of the ecosystem, for example valued using a stumpage value or resource rent, and will be distinct from the benefits, namely the harvested timber, commonly in the form of logs, that is sold by the forester.

10.57 Following the treatments of ecosystem services described in chapter 6, the scope of ecosystem services included in the net present value calculation may include flows of intermediate services. Thus, in principle, the returns estimated for a given ecosystem asset should include the supply of intermediate services to other ecosystem assets and should deduct the use of intermediate services from other ecosystem assets. Intermediate services that are supplied and used within an ecosystem asset need not be included in the calculation since they will net out in the overall valuation.

10.58 For marine ecosystems, attention should be paid to determining the appropriate measurement boundary for fish stocks and other aquatic resources since these stocks may

[109] The SEEA Central Framework describes alternative approaches to the valuation of timber resources (paras. 5.383 & 5.384) noting that they are NPV formulations under simplifying assumptions concerning the timber stock.

migrate through or straddle the EAA boundary if this is defined following, for example, a country's EEZ. The measurement boundary for fish stocks defined in the SEEA Central Framework (section 5.9) should be applied for these provisioning services.

10.59 The monetary value of abiotic flows, spatial functions and non-use values, defined following the treatments in chapter 6, should not be included in the valuation of ecosystem assets. However, the net present value of these flows may be distinctly calculated, for example concerning renewable energy sources, and included as part of other environmental assets in the extent balance sheet described in chapter 11.

10.3.3 Valuation of returns

10.60 Returns for each ecosystem service are valued based on exchange values consistent with the advice in chapters 8 and 9. The value of ecosystem services focuses only on the contribution of the ecosystem following the methods described in chapter 9. Where the ecosystem service values are based on observed market prices for associated benefits (e.g., in the resource rent method), the costs incurred in supplying the ecosystem services will be excluded such that the value used considers only the contribution of the ecosystem. The other methods described in chapter 9 all estimate directly the ecosystem contribution and exclude costs of supply.

10.61 To determine the present value of the future returns, assumptions are required concerning the future prices for each ecosystem service. When valuing individual environmental assets, such as mineral and energy resources, it is common for national accounting purposes to assume that the current period price (or an average of prices in recent accounting periods) will apply in future periods. This is also an appropriate default approach for ecosystem accounting purposes.

10.62 Nonetheless, in valuing future returns of ecosystem services, assuming constant prices may not be valid in some situations in view of the wider interconnections and factors that will influence an ecosystem asset and which will affect future returns. Therefore, future price changes should be taken into account when expected changes in markets are well-understood and where sufficient information is available, such as with some aspects of climate change related effects.

10.3.4 Future flows of services in physical terms

10.63 In estimating future flows of ecosystem services in an asset valuation context, it is necessary to allow for relationships among ecosystem services. While each ecosystem service is assumed to be measured separately from other ecosystem services and can be quantified separately in the current accounting period, the estimation of future flows requires recognition that expectations about patterns of ecosystem management and wider environmental trends for a single ecosystem asset will affect different ecosystem services in different ways. Thus, for example, if global climate regulation services are estimated under the assumption that a forest can sequester carbon over an infinite time frame, while for the same ecosystem asset, rates of timber provisioning are estimated under the assumption that the forest's timber resources will be fully depleted within a limited time frame (e.g., 30 years) with no likelihood of regeneration, then the two estimates of expected service flows will be internally inconsistent.

10.64 More specifically, the future flow of services depends upon the condition and regeneration of the ecosystem and future demand for ecosystem services, recalling that the supply and use of ecosystem services must align for accounting purposes. For example, the future flow of ecosystem services from a forest ecosystem in relation to air filtration services will depend in part on (a) the extent and condition of the forest; (b) the expected level of pollutants; and (c) the expected size and growth of the local population who benefit from air filtration services. There will be a set of factors to consider for each type of ecosystem service. Note that in estimating the expected future flow of services, it cannot be necessarily assumed that the flow will be ecologically sustainable, i.e., with no loss of ecosystem condition.

10.65 It is not anticipated that compilers will develop comprehensive models of future demand and supply considerations. However, it is reasonable to consider that some factors may be identifiable and quantifiable in certain contexts, for example the effects of increases in population or from the adoption of specific legislation that is expected to reduce pollution. Also, in some cases there may be bioeconomic and similar models that can support the development of estimates. In these cases, such information should be considered in the estimation of future flows for a given ecosystem service. Over time, as a time series of ecosystem accounts is developed, insights should emerge as to the factors of most relevance. Indeed, a key application of the accounts is the organisation of past data to estimate future trends. The following points are set out to outline relevant considerations.

10.66 Since ecosystem services require both the supply and use of services, the expected socio-economic context must also be considered in estimating the future flows of ecosystem services. This context will include general socio-economic factors (such as demography and incomes) as well as more specific factors, including those that are spatially relevant or relevant to individual ecosystem services. Examples include the changes in the demand for recreation related services following increases in accessibility of ecosystems; and changes in regulations that reduce the concentrations of pollutants and thus reduce the demand for air filtration services.

10.67 In considering both the future supply and demand of ecosystem services it will be helpful to frame the future flows differently depending on the type of service. Future flows of provisioning services are likely to be functions of natural resource and cultivated biological resource supply and demand considerations. On the other hand, future flows of regulating and maintenance services are more likely to be functions of changes in exposure to risks over time, for example from pollution and emissions, floods and the effects of climate change. Cultural services are likely to be driven by demand considerations including demographic changes and specific factors such as urban design and trends in tourism and recreation. The information provided in the logic chains for ecosystem services in annex 6.1 may provide a useful starting point in framing the relevant factors by type of ecosystem service.

10.68 As introduced in chapter 8, there are interactions among and within ecosystem assets that should be taken into account when considering the future flows of ecosystem services and their values. Assumptions concerning the expected future degradation which impact on specific ecosystem services will be of particular importance. For example, expectations of the degradation of forests due to high levels of current ecosystem use, would be expected to affect the regeneration rates, and consequently, the flow of wood provisioning services would be expected to decline over time. In national accounting, similar assumptions are made when estimating the stock of produced assets.

10.69 In addition, in order to avoid internal contradictions in the measurement of asset values, it should be recognised that some patterns of use, primarily concerning overexploitation of natural resources such as timber, soil or fish, will have detrimental impacts on the supply of other ecosystem services. These impacts may not be apparent immediately but will be subject to different environmental thresholds. In considering these issues, the measurement of ecosystem capacity as described in chapter 6 may provide valuable input.

10.70 Finally, it will be relevant to consider wider environmental changes, such as expected changes in rainfall and temperature patterns or ocean acidification associated with climate change. Ideally, information from climate change related models may be applied.

10.71 There are some contexts in which economic activity, including household consumption, has indirect and potentially delayed impacts on ecosystem condition. In a net present value framing, the fact that the impacts on ecosystem condition (and hence ecosystem service flows) may arise well into the future is conceptually straightforward to manage, if the timing and magnitude of the impacts is known and can be incorporated into the estimation process. However, a common scenario might be that evidence of impacts emerges gradually such that the expectations of future service flows change. From an accounting perspective, identifying such a change in expectations is possible. It is recommended that the change in value associated with these new expectations is recorded as a reappraisal of the value of the ecosystem asset.

10.3.5 Asset lives

10.72 ***Ecosystem asset life is the time over which an ecosystem asset is expected to generate ecosystem services.*** Estimates of the asset life should be based on consideration of the condition of the ecosystem asset and its capacity to supply the set of ecosystem services being considered in the valuation of the ecosystem asset. It is possible to assume an infinite asset life when it is expected that the ecosystem asset will be used long into the future. An alternative setting is to apply a maximum asset life of 100 years. Unless there is strong evidence to the contrary, it is recommended that estimates of asset life be based on patterns of ecosystem use that have occurred in the recent past rather than through the use of general assumptions about future sustainability or intended or optimal management practices.

10.73 For the application of the NPV formula, it is necessary to apply the same asset life for all ecosystem services supplied by an individual ecosystem asset. That is, the concept of the asset life should be applied in relation to the asset rather than the service. For ease of application of this requirement, it is most likely appropriate to assume a single asset life for all ecosystem assets and hence all ecosystem services. An infinite asset life might be most appropriate for this purpose. Then, if there are some services for which the expectation is that services will no longer be supplied or used after a particular point in time, e.g., after 30 years, the subsequent time periods can be filled with zeros.

10.3.6 Expected institutional arrangements

10.74 The final aspect in establishing the expected future returns is forming expectations about future institutional arrangements. The starting assumption for accounting purposes is that the current institutional arrangements will continue to apply. However, in cases where it is strongly expected that these arrangements will change in the future and the nature of the changes can be clearly understood, the effects of future changes in institutional arrangements and the expected timing of the changes should be factored in when estimating the future returns of ecosystem services. Examples of relevant institutional arrangements include natural resource management regimes, taxation arrangements, government environmental conservation programs and markets for environmental services (e.g., carbon markets).

10.3.7 Discounting

10.75 A discounting process involving the selection of a discount rate is required to derive net present value estimates. Annex A5.2 of the SEEA Central Framework summarises key issues in the choice of discount rates and describes the mathematical and analytical implications of the choice of discount rates. In particular, it notes the distinction between individual/private discount rates and social discount rates and whether those rates are determined descriptively or prescriptively. Descriptively-determined discount rates are those based on the prices (and other measurable factors) facing either individuals or governments, while prescriptively-determined discount rates incorporate assumptions regarding the preferences of individuals and societies, particularly in respect of equity between and within generations.[110]

10.76 For individual ecosystem assets such as mineral and energy resources, and timber resources, the SEEA Central Framework concludes that for the purpose of alignment with the concept of exchange values as defined in the SNA it is necessary to use marginal, private, market-based discount rates. This reflects that the discount rates are being applied in the context of the preferences of economic units operating from a private, market-based perspective. In the SEEA EA, the preferences relating to a wider range of economic units and goods and services need to be considered.

10.77 In this context, the following conceptual framing should be applied in selecting a discount rate:[111]

- Individual, market-based discount rates should be applied in the valuation of ecosystem services whose users are private economic units;
- Social discount rates should be applied in the valuation of ecosystem services that contribute to collective benefits, i.e., received by groups of people or society generally.

10.78 The selection of a social discount rate for SEEA EA purposes should be based on rates as specified in relevant government guidelines and further, the rates should be in active use in government decision making. These rates are likely to embody some assumptions on preferences of individuals and societies. Where such rates are not available, compilers may consider using long-term government bond rates. It is not expected that all countries will use the same discount rate given variations in economic context and institutional arrangements. The consistent application of the conceptual framing outlined above will however support comparability across countries.

10.79 In applying discount rates, it is recommended that compilers use a constant rate over the asset life. The primary alternative is to use declining discount rates including hyperbolic, gamma and geometrically declining rates. Declining rates may have some intuitive appeal in that they do not fix the relationship of preferences across generations and hence allow the preferences of future generations to be more explicitly considered. Declining rates also allow for increasing uncertainty, especially concerning future income growth. However, there are a range of theoretical (e.g., time inconsistency) and practical challenges, and hence these rates are not recommended for use in ecosystem accounting.

10.80 Care should also be taken to ensure that the discount rate applied is consistent with the assumptions made in projecting future returns of ecosystem services. Specifically, if future returns are estimated in nominal prices then the discount rate should include an allowance

[110] SEEA Central Framework, annex A5.2 Discount rates, para. A5.52.

[111] This framing is consistent with the idea of "dual discounting" (Baumgärtner et al., 2015; Weikard & Zhu, 2005) recognising that ideally this approach would also take into consideration the substitution effects between the types of services with different discount rates. These effects would generally be reflected in future prices.

for expected inflation. Most commonly, future returns will be estimated in real terms and thus the discount rate applied should also be in real terms. Since the essential function of a discount rate is to reflect the time value of money, the appropriate measure of expected inflation is likely to be one that is economy-wide in scope, for example, the GDP deflator.

10.81 Compilers are encouraged to undertake an assessment of the sensitivity of monetary valuations to different assumptions, in particular through the application of alternative discount rates. Such assessments can be published as part of the general documentation of the accounts.

10.3.8 Measuring changes in the net present value of ecosystem assets over an accounting period

10.82 Accounting for the change in the value of assets over an accounting period is a core part of asset accounting. As with the assessment of the value of an asset at the beginning and end of an accounting period, the valuation of changes in the asset value, such as those due to ecosystem enhancement, degradation and conversions, is also dependent on the impact that these changes have on expected future returns. Further, since these changes are not usually evidenced by transactions in the assets themselves, their valuation requires the use of the NPV approach to ensure alignment between opening and closing valuations and valuations of the changes.

10.83 A complete accounting for NPV and changes in NPV is presented in annex 10.1. The annex highlights the relationships between the changes in the quantities of expected flows of ecosystem services, changes in the condition and extent of the ecosystem asset, and changes in the prices of ecosystem assets with respect to each ecosystem service. A key conclusion demonstrated in the annex is that it is incorrect to use the unit price of the ecosystem service in the current period to value the ecosystem assets and changes in those assets. Rather the relevant asset prices will be a function of the NPV formula in which expected future returns and discounting will have an effect. The relationship between unit prices for ecosystem services and ecosystem asset prices is also discussed in the annex.[112]

[112] This relationship was described in relation to the valuation of individual environmental assets in the SEEA Central Framework, annex 5.1

Annex 10.1: Application of the net present value method for valuing ecosystem assets and changes in ecosystem assets

Introduction

A10.1 This annex explains, in some detail, the steps involved in implementing a net present value (NPV) approach for the valuation of ecosystem assets, with a view to deriving valuations of the opening and closing values of ecosystem assets and consistent measures of ecosystem enhancement, degradation, conversions, other changes in volume and revaluations. The conceptual framing for the approach described here is explained in chapter 10 together with definitions of the relevant accounting entries.

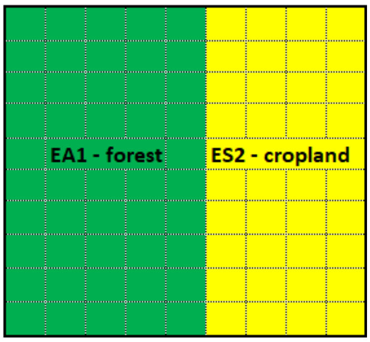
A10.2 A simple, stylized example is used to demonstrate the approach. It is recognized that the application of these principles will be more complex in practice and also that some variations in application will be needed for ecosystem services other than the ones used. A more complete stylised example is presented at the end of this book. It involves more ecosystem types and ecosystem services and incorporates a full range of ecosystem accounts including extent accounts, condition accounts, ecosystem service flow accounts and monetary ecosystem asset accounts. At the same time, the accounting principles described in this annex are also applied in that broader example noting some differences in assumptions that are described below at the appropriate time.

Stylized example

A10.3 In this simple example the EAA covers 90 hectares (ha) consisting of two ecosystem assets – forest and cropland. At t_0 [113] the forest (EA1 - green) covers 50 ha and the cropland (EA2 - yellow) covers 40 ha (see Figure 10.1). It is assumed that the extent of each ecosystem asset remains the same from t_0 to t_1 , thus changes in ecosystem service flows are driven by changes in condition (degradation or enhancement) or changes in prices. The situation where ecosystem conversion takes place is discussed later in this annex.

Figure 10.1: Extent at t_0

Ecosystem asset	**a_0**
EA1 - forest	50 ha
EA2 - cropland	40 ha



A10.4 The forest is assumed to supply three ecosystem services: wood provisioning services (ES1), global climate regulation services (ES2) and recreation-related services (ES3), and the cropland

[113] Accounting periods are measured over time, where t_1 is the end of the first accounting period, t_2 is the end of the second accounting period and so on. t_0 is the start of the first accounting period and reflects the initial characteristics of the ecosystems and the initial expected prices and quantities of ecosystem services. Accounting periods are assumed to be years. To provide context, the first accounting period year 1 could be 2020 (which would start at t_0 and end at t_1) and year 2 could be 2021 (which would start at t_1). Further, note that in this example t_0 will also be the end of the accounting period for 2019.

supplies one ecosystem service: crop provisioning (ES4). It is further assumed that each of these services is supplied only from the specific areas of each ecosystem asset such that the service providing areas of each ecosystem service and time t (denoted by a_t) coincide with the areas of the respective ecosystem assets.

A10.5 As explained in section 10.3, the value V_t of each ecosystem asset is derived as the NPV of the future flows of each ecosystem service that the ecosystem asset supplies. In this example, as shown in Table 10.2, it is assumed that unit prices *p* and quantities of ecosystem services supplied *q* are known and have been projected for each ecosystem service for a future period of 5 years.[114]

A10.6 Table 10.2 depicts the set of unit prices and total quantities of ecosystem services supplied across the EAA as expected at t_0 (covering years 1 to 5) and Table 10.3 depicts the prices and quantities as expected at t_1 (covering years 2 to 6). The expected prices and quantities shown in Table 10.2 and Table 10.3 for each of the four ecosystem services supplied across the EAA are different between t_0 and t_1 reflecting differences in expectations at these two points in time. Further, in this example the pattern of expected prices and quantities shows changes over the 5 year asset life. In the stylised example at the end of the SEEA EA, the pattern of expected prices and quanities is assumed to be constant over the entire asset life.

[114] In this example we have worked with a moving asset life of 5 years (for illustrative purposes only), rather than assuming a fixed asset life end date, which has an effect on the results obtained. However, in more realistic applications, the asset life would be multiple decades (or infinite as we are dealing with renewable assets) and this effect would become minimal. In the stylised example at the end of this book an asset life of 100 years is assumed.

Table 10.2: Input data and NPV calculations for three ecosystem services at time period t_0

Variable	Ecosystem service	Unit	Year 1	Year 2	Year 3	Year 4	Year 5	Total flow (Q_0)	Total NPV (V_0)	Average prices (p_0)
ES quantity supplied (a)	ES1_Wood provisioning	m^3	12	12	12	12	12	60		
	ES2_Global climate regulation	tCO_2	140	142	144	146	148	720		
	ES3_Recreation-related	visits	190	190	190	200	200	970		
	ES4_Crop provisioning	t	5	6	6	7	7	31		
Unit price (b)	ES1_Wood provisioning	$/m^3$	$60	$62	$64	$66	$70			
	ES2_Global climate regulation	$/tCO_2$	$25	$26	$27	$28	$29			
	ES3_Recreation-related	$/visit	$5	$5	$6	$6	$6			
	ES4_Crop provisioning	$/t	$75	$75	$75	$75	$75			
Exchange value (c) = (a) * (b)	ES1_Wood provisioning	$	$720	$744	$768	$792	$840			
	ES2_Global climate regulation	$	$3,500	$3,692	$3,888	$4,088	$4,292			
	ES3_Recreation-related	$	$950	$950	$1,140	$1,200	$1,200			
	ES4_Crop provisioning	$	$375	$450	$450	$525	$525			
Discount factor (d)	2% discount rate		0.9800	0.9604	0.9412	0.9224	0.9039			
Net present value (e) = (c) * (d)	ES1_Wood provisioning	$	$706	$715	$723	$731	$759		$3,633	$61
	ES2_Global climate regulation	$	$3,430	$3,546	$3,659	$3,771	$3,880		$18,285	$25
	ES3_Recreation-related	$	$931	$912	$1,073	$1,107	$1,085		$5,108	$5
	Total Forest	$							$27,026	
	ES4_Crop provisioning	$	$368	$432	$424	$484	$475		$2,182	$70
	Total Cropland	$							$2,182	
	Total EAA	$							**$29,208**	

Table 10.3: Input data and NPV calculations for three ecosystem services at time period t_1

Variable	Ecosystem service	Unit	Year 2	Year 3	Year 4	Year 5	Year 6	Total flow (Q_1)	Total NPV (V_1)	Average prices (p_1)
ES quantity supplied (a)	ES1_Wood provisioning	m^3	10	10	10	10	10	50		
	ES2_Global climate regulation	tCO_2	130	132	134	136	138	670		
	ES3_Recreation-related	visits	190	200	200	210	210	1,010		
	ES4_Crop provisioning	t	6	7	7	8	7	35		
Unit price (b)	ES1_Wood provisioning	$/m^3$	$65	$65	$67	$70	$72			
	ES2_Global climate regulation	$/tCO_2$	$26	$27	$28	$29	$30			
	ES3_Recreation-related	$/visit	$5	$6	$6	$6	$6			
	ES4_Crop provisioning	$/t	$75	$75	$75	$75	$75			
Exchange value (c) = (a) * (b)	ES1_Wood provisioning	$	$650	$650	$670	$700	$720			
	ES2_Global climate regulation	$	$3,380	$3,564	$3,752	$3,944	$4,140			
	ES3_Recreation-related	$	$950	$1,200	$1,200	$1,260	$1,260			
	ES4_Crop provisioning	$	$450	$525	$525	$600	$525			
Discount factor (d)	2% discount rate		0.9800	0.9604	0.9412	0.9224	0.9039			
Net present value (e) = (c) * (d)	ES1_Wood provisioning	$	$637	$624	$631	$646	$651		$3,188	$64
	ES2_Global climate regulation	$	$3,312	$3,423	$3,531	$3,638	$3,742		$17,647	$26
	ES3_Recreation-related	$	$931	$1,152	$1,129	$1,162	$1,139		$5,514	$5
	Total Forest	$							$26,349	
	ES4_Crop provisioning	$	$441	$504	$494	$553	$475		$2,467	$70
	Total Cropland	$							$2,467	
	Total EAA	$							**$28,816**	
	Change in EAA value	$							**-$392**	

A10.7 To simplify the presentation, the calculations are undertaken using discounted prices, assuming a 2% discount rate. Discounted prices are obtained by multiplying the unit price in year *j* with the applicable discount factor for year *j* (as shown in Table 10.2) to express the ecosystem service values in the price of the base year. For example, the value of wood provisioning of $723 in year 3 is calculated as the cubic metres of wood (12 m^3) times the unit price ($64 per m^3) times discount factor (0.9412). Table 10.2 shows the discount factors obtained using a 2% discount rate assuming the flows in the first year are discounted. This approach allows variations in the pattern of expected prices and quantities to be accounted for.

A10.8 For the derivation of the NPV, using the equation provided in section 10.3 - the value of the EAA, i.e., of all ecosystem services across all ecosystem assets – can be written as:

$$V_t = \sum_{i=1}^{i=4} \sum_{j=t+1}^{j=5} \frac{p_t^{ij} \, q_t^{ij}}{(1+r_j)^{(j-t)}} \qquad [1]$$

A3.30 In equation [1], V_t refers to the value at the end of accounting period *t*, and is based on expectations about future prices and quantities at that point in time; *i* denotes the ecosystem service, and *j* the year. Note that it is assumed that the value of each ecosystem service is separable and hence the overall asset value of the EAA can be obtained by summing over all ecosystem services.

A10.9 To explain the calculation for an individual ecosystem service, consider the global climate regulation service, ES2. Here the quantities range from 140 to 148 tonnes per year over the 5 years from t_0 and the unit prices increase each year, from $25 to $29 per tonne of carbon dioxide (e.g., as the marginal damages of carbon release increase). The net present value of this ecosystem service is derived by multiplying the quantity and the associated discounted unit price in each year (e.g., for t_0, Year 1 it is 140 tonnes of CO_2 *$25 per tonne of CO_2 * 0.98 = $3,430) and, summing over the five year asset life, the NPV for climate regulation at t_0 is $18,285.

A10.10 Using this approach across all ecosystem services and for both ecosystem assets, a total opening value at t_0 of $29,208 is obtained. This decreases to $28,816, the value at t_1, i.e., at the end of the accounting period. The change in asset value is -$392. Note that in the calculations, an NPV for each ecosystem service and each ecosystem type is also obtained.

Decomposition of the change in NPV

A10.11 In order to compile the entries in the ecosystem monetary asset account that record changes in the NPV between opening and closing values, it is necessary to distinguish between changes due to prices and changes due to volumes (quantities). To distinguish these different changes, V_t^i (the value of the ith ecosystem service) is defined as the product of (i) the average (discounted) unit price over the asset life, denoted by $\bar{p}_t^i$; and (ii) the total flow (cumulative quantity) of ecosystem services supplied over the asset life, denoted by Q_t^i.[115]

A10.12 Table 10.2 details the various $\bar{p}_t^i$ and Q_t^i for each ecosystem service. To illustrate the derivation of the $\bar{p}_t^i$ consider the global climate regulation service, ES2. Here the NPV at t_0 is V_0^2=$18,285 and the cumulative quantity Q_0^2 over the 5 years from t_0 is 720 tonnes of CO_2.

[115] This average, discounted unit price is derived in a similar manner to the approach taken in the SEEA Central Framework (annex 5.1) to derive estimates of depletion, where the *asset price in situ* for a subsoil asset was defined as the ratio of its NPV value V and the total stock S.

Dividing the NPV value by the total volume (V_0^2/Q_0^2) gives the average discounted unit price $\bar{p}_0^2$ for ES2 of \$25.40 per tonne CO_2.

A10.13 Using this framing, equation [1] can be re-expressed to obtain:

$$V_t \; = \sum_{i=1}^{4} \bar{p}_t^i Q_t^i \qquad [2]$$

$$V_1^i - V_0^i = \bar{p}_1^i Q_1^i - \bar{p}_0^i Q_0^i = (\bar{p}_1^i - \; \bar{p}_0^i)Q_1^i + \; \bar{p}_0^i Q_1^i - \bar{p}_0^i Q_0^i$$

$$= \; \underbrace{(\bar{p}_1^i - \; \bar{p}_0^i)Q_1^i}_{\text{Price effect}} + \; \underbrace{\bar{p}_0^i(Q_1^i - Q_0^i)}_{\text{Volume effect}} \qquad [3]$$

A10.14 Equation [3] reflects the decomposition of the change in NPV for each ecosystem service i, into changes due to price (price effect) and changes due to volume/quantity (volume effect). The change in price $(\bar{p}_1^i - \bar{p}_0^i)$ is given a weight Q_1^i and the change in volume $(Q_1^i - Q_0^i)$ is given a weight of $\bar{p}_0^i$. However, this weighting pattern (or decomposition form) is not unique and the change in value could have been decomposed into $(\bar{p}_1^i - \bar{p}_0^i)Q_0^i + \bar{p}_1^i(Q_1^i - Q_0^i)$. Thus, different weights for the price and volume effect are derived. As in SEEA Central Framework, annex 5.1, and following standard index number practice, the average of the two decomposition forms is used to generate the results shown below.

A10.15 Using the various $\bar{p}_t^i$ and Q_t^i for each ecosystem service, the results using both decomposition forms can be calculated and averaged to derive average price and volume effects. The average price and volume effects for each ecosystem service are shown in Table 10.4. The key observation is that the total of both of the decomposition effects have to be equal to the overall change in value of -\$392 shown in Table 10.2 above. In other words, the decomposition is exact.

A10.16 Table 10.4 shows that the total value change of -\$392 reflects the combination of a positive price effect (\$1,027) and a negative volume effect (-\$1,419). The decomposition thus provides additional insight into the nature of the change in total value. This type of analysis can also be undertaken for individual services. For example, there is a large reduction in the value of global climate regulation (-\$639), which is mostly explained as a volume effect (Q_t^1 drops from 720 to 670 tonnes of CO_2, see Table 10.2 and Table 10.3). At the same time, there is an upward price effect due to the increasing price path of the service. Note too that there is a minimal price effect for crop provisioning services reflecting that its expected price path does not change.

Table 10.4: Results of the decomposition analysis for four ecosystem services (currency units)

	Price effect	Volume effect	Total
ES1 – Wood provisioning	\$177	-\$622	-\$444
ES2 – Global climate regulation	\$655	-\$1,293	-\$639
ES3 – Recreation-related	\$192	\$215	\$406
ES4 – Crop provisioning	\$4	\$282	\$285
Total	**\$1,027**	**-\$1,419**	**-\$392**

Ecosystem monetary asset account

A10.17 The various decomposition elements can now be used to compile the ecosystem monetary asset account, as shown in Table 10.5. The account is structured to show the opening and closing values for each ecosystem asset (equal to the sum of the NPV of the ecosystem services relevant for that ecosystem asset)[116] and the various changes due to enhancement, degradation, conversions, revaluations or other changes. An explanation of the allocation of the accounting entries is provided in Table 10.6.

Table 10.5: The ecosystem monetary asset account (currency units)

	Forest	Cropland	Total
Opening stocks at t_0	\$27,026	\$2,182	\$29,208
Ecosystem enhancement		\$282	\$282
Ecosystem degradation	-\$1,915		-\$1,915
Ecosystem conversions			
Additions		\$0	\$0
Reductions	\$0		\$0
Other changes in volume of ecosystem assets			
Catastrophic losses			
Reappraisals	\$215		\$215
Revaluation	\$1,023	\$4	\$1,027
Net change in value	-\$677	\$285	-\$392
Closing stocks at t_1	\$26,349	\$2,467	\$28,816

A10.18 The estimates for the opening and closing values for each ecosystem asset can be readily obtained from Table 10.2 and Table 10.3. For Forests, it is the sum of the NPV for ES1, ES2 and ES3 and for Cropland, it is the NPV for ES4. To complete the other accounting entries the first focus is to estimate the entry for revaluations which is equal to the price effect shown in Table 10.4. This equality applies since the price effect measures the change in value that occurs solely due to the change in average (discounted) price (for each ecosystem service). A final section of the annex discusses the relationship between unit prices of ecosystem services and asset prices.

A10.19 The remaining change in value is associated with the volume effect which measures changes in the total quantity of expected future ecosystem services (for each ecosystem service) due to changes that occur during the accounting period, excluding the effects of price changes. The volume effects can therefore be used to determine the relevant entries for ecosystem enhancement, degradation, reappraisals and catastrophic losses depending on the cause of the change following the definitions provided in in chapter 10.

A10.20 The process of establishing how a volume effect for a given ecosystem service is treated entails considering (i) whether the volume effect is positive or negative; (ii) the change in ecosystem

[116] In this example, the process is made more straightforward since there is a 1-1 correspondence between the EAs and the service providing areas of the ecosystem services. In more complex settings, the value of the individual ecosystem services would need to be apportioned to the underlying ecosystem assets (i.e., when an ecosystem service is supplied over a combination of EAs). This may be undertaken by pro-rating the aggregate supply of the ecosystem service using the share of areas of the relevant EAs in which case there is an assumption of homogeneous distribution of supply of the ecosystem service across the service providing area. More complex allocation methods might also be applied.

condition over the accounting period; and (iii) the change in the demand for ecosystem services.[117] By considering the various combinations the appropriate treatment of the measured volume effect can be made following the guidance in Table 10.6. For example, if the change in volume is positive and the change in condition is also positive, then the volume change is recorded as ecosystem enhancement. There are two combinations that are not possible since where condition and demand move in the same direction (either up or down), the volume cannot move in the opposite direction – i.e., it would imply that the future flow of ecosystem services in physical terms was not correlated with either the condition of the ecosystem or the demand for the services.

A10.21 In case of significant unexpected changes in quantities (e.g., due to a hurricane uprooting trees), negative changes in volume could be recorded as catastrophic losses rather than degradation. In this way, all possible entries of the monetary asset account can be obtained, in a manner that is aligned with and uses information from the extent accounts, condition accounts and ecosystem service supply and use accounts.

Table 10.6: Attributing volume effects based on cause

Volume change	Condition change	Demand change	Accounting entry
up	up	up	Enhancement
up	up	down	Enhancement
up	down	up	Upward reappraisal
up	down	down	Not possible
down	up	up	Not possible
down	up	down	Downward reappraisal
down	down	up	Degradation
down	down	down	Degradation

A10.22 To apply the guidance from Table 10.6 in this example, it is assumed that the associated condition account indicates that the condition of the forest ecosystem asset has declined during the accounting period, but the condition of the cropland ecosystem asset has increased. Considering each ecosystem service in turn:

- For wood provisioning services (ES1), Table 10.4 shows a negative volume effect (-$622). Since the condition also declines this volume effect is recorded as degradation.
- For global climate regulation services (ES2), Table 10.4 shows a negative volume effect (-$1,293). Since the condition also declines this volume effect is recorded as degradation.
- For recreation-related services (ES3), Table 10.4 shows a positive volume effect ($215). Since the condition declines, this is best explained as being due to an increase in demand (reflected in a slight increase in total expected visitor numbers) and hence recorded as an upward reappraisal.

[117] In projecting physical flows and unit prices (p's and q's in Table 10.2), it is reasonable to assume that ecosystem condition (and expectations how it will develop within the current management regime) and expected demand is taken into account. During the accounting period, many changes happen (changes in demand, but also changes in actual condition), with the end result that at the end of the accounting period there will be updated expectations about the physical flows and unit prices.

- For crop provisioning services (ES4), Table 10.4 shows a positive volume effect ($282). Although demand is assumed to decline slightly, since condition improves, this volume effect is recorded as ecosystem enhancement.

A10.23 The broader interpretation is that the overall value of the forest ecosystem asset has declined, while the cropland ecosystem asset has increased in value; the net effect is however a loss of $392 in the value of this EAA.

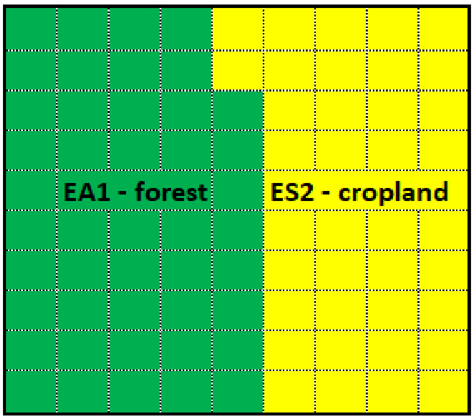
Decomposition of the change in NPV with ecosystem conversions

A10.24 In the example above, the areas of each ecosystem asset remained the same over the projection period. Consequently, there was no consideration of ecosystem conversions, i.e., changes in ecosystem extent where a particular location changes in ecosystem type during an accounting period. These changes are recorded in biophysical terms in the ecosystem extent account. The following explains the appropriate calculations for recording the monetary effects of conversions in the monetary ecosystem asset account.

A10.25 To demonstrate the relevant entries, the example is adapted such that the extent of the forest is reduced by 2 ha during the accounting period and converted to cropland (see Figure 10.2). To retain the connection with the previous context and data, a simplifying assumption is made in which all other details of expected quantities and unit prices remain the same and consequently the NPV for each ecosystem service and the total NPV for the EAA remains the same. Therefore, the difference implied by the ecosystem conversion is that the change values from forest to cropland must be accounted for.

Figure 10.2: Extent at t_1

Ecosystem asset	a_1
EA1 - forest	48 ha
EA2 - cropland	42 ha



A10.26 To incorporate changes in area of each ecosystem asset, the decomposition formula is re-worked such that the extent of each ecosystem service's service providing area – denoted by a_t^i – is incorporated. This incorporation is shown in equation [4] which is a rewriting of equation [2].

$$V_t^i = \bar{p}_t^i \frac{Q_t^i}{a_t^i} a_t^i = \bar{p}_t^i \bar{q}_t^i a_t^i \qquad [4]$$

A10.27 Here $\bar{q}_t^i$ denotes the total (expected) volume of ecosystem service *i* per hectare within the service providing area. Using this expansion, the difference between the opening and closing value for each ecosystem service can be expressed as:

$$\begin{aligned} V_1^i - V_0^i &= \bar{p}_1^i \bar{q}_1^i a_1^i - \bar{p}_0^i \bar{q}_0^i a_0^i = (\bar{p}_1^i - \bar{p}_0^i)\bar{q}_1^i a_1^i + \bar{p}_0^i \bar{q}_1^i a_1^i - \bar{p}_0^i \bar{q}_0^i a_0^i \\ &= (\bar{p}_1^i - \bar{p}_0^i)\bar{q}_1^i a_1^i + \bar{p}_0^i(\bar{q}_1^i - \bar{q}_0^i)a_1^i + \bar{p}_0^i \bar{q}_0^i a_1^i - \bar{p}_0^i \bar{q}_0^i a_0^i \\ &= \underbrace{(\bar{p}_1^i - \bar{p}_0^i)\bar{q}_1^i a_1^i}_{\text{Price effect}} + \underbrace{\bar{p}_0^i(\bar{q}_1^i - \bar{q}_0^i)a_1^i}_{\text{Volume (intensity) effect}} + \underbrace{\bar{p}_0^i \bar{q}_0^i (a_1^i - a_0^i)}_{\text{Area effect}} \qquad [5] \end{aligned}$$

A10.28 Formula [5] thus decomposes the change in NPV (of each ecosystem service *i*) into 3 effects: a price effect, a volume (intensity) effect and an area effect. As before, the price effect measures the change in average (discounted) unit prices that occurs during the accounting period. The volume (intensity) effect measures changes in total quantity of future ecosystem services but now normalized to be shown per hectare, hence the reference to intensity. The area effect measures changes in value due to changes in extent of the assets.

A10.29 As with the earlier decomposition into price and volume effects (equation [3]), the decomposition form shown in equation [5] is exact but not unique. In fact, there are six alternative exact formulations of equation [5], compared to the two alternative formulations of equation [3].[118] The results shown below are derived using a weighted average of each of the six forms of (i) the area effect, (ii) the price effect and (iii) the volume (intensity) effect. To derive the actual effects the change in the relevant variable (e.g., area) are multiplied by these weights. In our example, the derivations of the three effects are the following:

Area effect: $\left[\frac{1}{3}\bar{p}_0^i\bar{q}_0^i + \frac{1}{6}\bar{p}_0^i\bar{q}_1^i + \frac{1}{6}\bar{p}_1^i\bar{q}_0^i + \frac{1}{3}\bar{p}_1^i\bar{q}_1^i\right] * (a_1^i - a_0^i)$

Price effect: $\left[\frac{1}{3}\bar{p}_0^i a_0^i + \frac{1}{6}\bar{p}_0^i a_1^i + \frac{1}{6}\bar{p}_1^i a_0^i + \frac{1}{3}\bar{p}_1^i a_1^i\right] * (\bar{p}_1^i - \bar{p}_0^i)$

Volume effect: $\left[\frac{1}{3}a_0^i\bar{q}_0^i + \frac{1}{6}a_0^i\bar{q}_1^i + \frac{1}{6}a_1^i\bar{q}_0^i + \frac{1}{3}a_1^i\bar{q}_1^i\right] * (\bar{q}_1^i - \bar{q}_0^i)$

A10.30 To calculate this decomposition, $\bar{q}_0^i$ are used that are obtained by dividing, for example, the total quantity of global climate regulation services at t_0, i.e., Q_0^2 (720 tonnes of CO_2), by the service providing area a_0^2 (50 ha) resulting in $\bar{q}_0^1$ of 14.40 tonnes of CO_2 per ha. Following the same steps as before, but with the extension to consider the effect of the change in area, the decomposition of the change in value can be calculated as shown in Table 10.7.

Table 10.7: Results of the decomposition analysis (3 factors) (currency units)

	Area effect	Volume effect	Price effect	Total
ES1 – Wood provisioning	-\$139	-\$482	\$177	-\$444
ES2 – Global climate regulation	-\$733	-\$560	\$654	-\$639
ES3 – Recreation related services	-\$217	\$431	\$192	\$406
ES4 – Crop provisioning	\$113	\$168	\$4	\$285
Total	-\$976	-\$442	\$1,027	**-\$392**

A10.31 Again, the decomposition is exact as the sum of the changes due to area, volume and price equals the total value change of -\$392. As expected, the differences in NPV for each ecosystem service are the same (e.g., -\$444 for ES1 as before), but we now have three explaining factors rather than two. Also as expected, the price effect is virtually the same as in the earlier decomposition, since we have essentially split the volume effect into a volume (intensity) effect and an area effect. The area effect can now be interpreted as providing the entries for ecosystem conversions (additions and reductions) in the ecosystem monetary asset account. It should be noted that the change in area used to derive the area effect is consistent with the information in the ecosystem extent account.[119]

A10.32 The structure of the ecosystem monetary asset account remains unchanged – see Table 10.8, but compared to the results shown in Table 10.5, the entries for ecosystem conversions are

[118] To see this, notice that in equation [3] the starting point was p_1 as a difference, but we could have also started with q_1. In equation [5] this is extended to also consider starting with a_1. See Dietzenbacher & Los (1998) for a more general proof.

[119] Note that there will be some interactions between changes in volume and changes in price in a general equilibrium context but the effect of these interactions is likely to be minimal.

now non-zero. The main change is that the previous entry for degradation of forests (-$1,915) is reduced to -$611 and the remainder is recorded as a negative ecosystem conversion (-$1,090). A similar partitioning occurs with cropland with the previous entry for ecosystem enhancement reduced to $168 and a positive ecosystem conversion of $113 recorded. By including an additional factor to the decomposition form, we can now better explain the change in value that occurred during the accounting period.

Table 10.8: Monetary ecosystem asset account (with conversions)

	Forest	Cropland	Total
Opening stocks at t_0	$27,026	$2,182	$29,208
Ecosystem enhancement		$168	$168
Ecosystem degradation	-$611		-$611
Ecosystem conversions			
Additions		$113	$113
Reductions	-$1,090		$1,090
Other changes in volume of ecosystem assets			
Catastrophic losses			
Reappraisals			
Revaluation	$1,023	$4	$1,027
Net change in value	-$677	$285	-$392
Closing stocks at t_1	$26,349	$2,467	$28,816

Unit prices and asset prices

A10.33 Finally, a word on the interpretation of prices. In this valuation and decomposition, discounted unit prices have been used for each ecosystem service. After multiplying the discounted unit prices (p_t^{ij}) with their expected quantities (q_t^{ij}) and summing over the asset life, we obtain the NPV of each ecosystem service and from there the value of each ecosystem asset at each point in time can be determined.

A10.34 In this context, the NPV of the ecosystem asset (i.e., the sum over relevant services) is also the unit price of the asset. Thus, the basic measurement unit remains the individual ecosystem asset, characterized by its extent (which will generally be greater than 1 ha) and its condition. In this framing, the price of the ecosystem asset can be considered to reflect an average asset price over all hectares for that ecosystem asset.

A10.35 It may also be of interest to calculate a marginal asset price defined as the change in NPV of the ecosystem asset with respect to a marginal change in extent of the ecosystem asset (e.g., a change of 1 ha).[120] In this framing, the intuition is that for a large asset (in terms of extent),

[120] The choice of extent for assessing marginal price is just one amongst several options, for instance it is also possible to consider ecosystem characteristics such as timber volume.

say a forest, it may be reasonable to suppose that the marginal price of a hectare at the edge of the forest will be different from the marginal price of a hectare at the centre of the forest, i.e., there are different asset prices for different parts of an ecosystem asset and these asset prices might change as the overall size of the ecosystem asset changes. Put differently, losing one hectare when the extent is 100 may be less problematic than losing one hectare when the extent is 5.

A10.36 In the example, it is assumed that the supply of ecosystem services is distributed homogenously across the ecosystem asset. This implies that the marginal and average asset price coincide by assumption. This is how, in order to separate out the area effect in the decomposition, it was possible to normalize the ecosystem services using the area over which they were supplied.

A10.37 Of course, in practice most ecosystem services are not supplied homogeneously across the ecosystem asset, and hence a difference between the marginal and average asset price would arise. In such instances, it would be theoretically possible to break-up the ecosystem asset into smaller units (e.g., units of 1 ha each), and for each obtain an average asset price following the approach described in this annex. Provided each small unit was homogenous, an alignment would emerge between the average and marginal asset prices at that smaller scale.

A10.38 Finally, the example provided here is framed in terms of individual ecosystem assets that provide ecosystem services. It is also possible to apply the same approach at an aggregate scale valuing ecosystem types based on the bundles of ecosystem services they provide.

11 Integrated and extended accounting for ecosystem services and assets

11.1 Introduction

11.1 The discussion of combining ecosystem accounting data with standard economic data is increasingly relevant as countries, both nationally and multi-nationally, are recognizing the losses of some ecosystem services and are developing policy instruments to mitigate and reverse this trend. The combination of ecosystem and economic data supports a richer discussion of the connection between ecosystems and people, underpins the development of indicators concerning this relationship, such as the contribution of ecosystem services to measures of economic production, and allows the derivation of adjusted national accounting aggregates such as degradation adjusted measures of net domestic product (NDP).

11.2 Building on the ecosystem accounts described through chapters 3 to 10, this chapter describes principles and recommendations for the integration of ecosystem accounting data and data from the standard SNA accounts. Integration is considered with respect to the supply and use tables and the sequence of institutional sector accounts, including balance sheets. All of these accounts are labelled as extensions to the SNA accounts recognising the intent to complement the data presented in the SNA.

11.3 Historically, the approaches to more detailed integration of ecosystem-related information with the national accounts have focused on the valuation of degradation and the appropriate recording of this "cost of capital" in the accounts of different sectors. This is a characteristic of the previous approaches outlined by national accountants (see, for example, Council (1999), A. Harrison (1993) and Vanoli (1995)). As explained in the SEEA 2012 EEA and in some recent literature (e.g., Edens & Hein (2013) and Obst et al. (2016)), the emergence and application of the concept of ecosystem services has enabled a reconceptualization of the integration of ecosystem-related data with the SNA. This basis for integration underpins much of the discussion in this chapter.

11.4 The monetary valuation of ecosystem services and ecosystem assets using exchange values is required for integration with the national accounts. However, as explained consistently through chapters 8, 9 and 10, in many instances data from the ecosystem extent and condition accounts and concerning the physical flows of ecosystem services are required to better understand relevant ecological thresholds and limits. Also, the coverage of the extended accounts will be limited to the ecosystem services that are within scope of measurement. Finally, the use of exchange values will provide monetary values that are suitable for the compilation of extended accounts but, in other contexts, alternative valuation concepts and presentations may be more appropriate. Complementary approaches to monetary valuation which are considered to reflect applications and extensions of the SEEA EA accounting framework are discussed in chapter 12.

11.5 Data from the ecosystem accounts also complement data from the SEEA Central Framework especially concerning environmental pressures (e.g., concerning emissions) and policy responses (e.g., concerning environmental protection expenditure, environmental taxes and subsidies). These types of data are needed for a complete assessment of the environmental-economic relationship. The potential to combine data from the SEEA Central Framework and the SEEA EA is discussed in chapter 13 using selected policy themes as the entry point.

11.2 Extended supply and use tables

11.6 Standard supply and use tables (SUT) show the relationships between economic units (households, business, governments) in terms of flows of goods and services. Each type of good or service is recorded as supplied by an economic unit and used by another, either for final consumption, intermediate consumption, investment (capital formation) or export. Inherent in the design of an SUT is the ability to record supply chains through the economic system by showing the gross outputs and intermediate inputs and how these are netted within each economic unit to derive measures of value added, i.e., the income generated through the production of goods and services. SUT are commonly used to support the compilation of measures of GDP as they require a complete reconciliation between the supply of, and demand for, goods and services and hence among the three different measures of GDP. Importantly, the scope of goods and services included in a standard SUT is limited to the production boundary of the SNA.

11.7 Compiling extended SUT involves combining data from the ecosystem services flow account in monetary terms described in chapter 9 with the standard SUT from the SNA as just described. Extended SUT thus require explicit consideration of the measurement boundaries between the economy and the ecosystems to ensure an appropriate structure for the accounts and to ensure that recorded data do not imply double counting. Extended SUT thus present the data on the supply and use of ecosystem services as extensions to the standard SUT compiled following the SNA.

11.8 The compilation of extended SUT can support range of purposes:

- showing the contribution of ecosystem services to the output and value added of different industries and the economy as a whole.
- identifying the share of economy wide value added that is dependent on ecosystem services.
- understanding the main users of ecosystem services and the relative contribution of ecosystem services to household and government final consumption expenditure.
- describing ecosystem services as inputs to economic supply chains and understanding the ecosystem service dependent industries.
- integration of ecosystem services data into analytical and modelling tools that use SUT data as primary data sources, for example input-output models and computable general equilibrium models.

11.9 There are two key aspects to consider in extending the standard SUT to incorporate ecosystem services. First, since ecosystem accounting implies an extension to the standard production boundary, the set of goods and services within scope of the extended SUT is broader and hence the dimensions of the standard SUT must increase. This would usually be carried out through the addition of new rows (each additional row representing an additional ecosystem service).[121]

11.10 The accounting requirement is to ensure that the ecosystem services are distinguished clearly from the goods and services (products) that are already recorded within the standard SUT. For the products to which ecosystem services are direct inputs (i.e., SNA benefits), ecosystem services are recorded as the intermediate consumption of the associated user of the

[121] SUT do not need to be square matrices – i.e., where the number of goods and services is equal to the number of supplying industries. The standard input-output matrix algebra that underpins input-output analysis has been adapted to allow non-square, SUT data to be used in I-O analysis and this can be applied in the case of extended SUT. Note that the resulting I-O tables are square matrices.

ecosystem service. For example, the ecosystem service of timber biomass provisioning is recorded as additional intermediate consumption by forestry units.

11.11 For ecosystem services that contribute to non-SNA benefits, there are no associated products with which to connect and it is sufficient to record the supply of the relevant ecosystem service (e.g., air filtration services) and the use of that service by the relevant economic unit following the advice in chapter 6.

11.12 It is possible to design an extended SUT that also incorporates intermediate services supplied by ecosystems. For example, where pollination services are of relevance, an additional row might be included to recognize these flows as inputs to the generation of associated final ecosystem services, e.g., biomass accumulation of crops. Note that intermediate services must be recorded as used by ecosystem assets and not recorded as inputs to economic units.

11.13 The second key aspect of the extended SUT entails the requirement that columns be added to reflect the source of the supply of ecosystem services. Thus, ecosystem assets (grouped by ecosystem type) are treated as additional producing units alongside the current set of industries (agriculture, manufacturing, etc.). A simple example is presented in annex 11.1 to demonstrate the steps involved in these extensions.

11.14 Table 11.1(a & b) shows an extended SUT incorporating a selected set of product groups and using the broad groups of ecosystem services from the monetary ecosystem services SUT from chapter 9. Note that after including additional rows for ecosystem services and additional columns for ecosystem assets, the extended SUT is completed by incorporating the standard value-added entries for industries and for ecosystem assets. Where ecosystem services are inputs to SNA benefits this has the effect of partitioning the operating surplus of the using industry (e.g., agriculture or forestry) such that the contribution of ecosystem services is deducted from that industry and shown as the output and operating surplus of the supplying ecosystem asset.

11.15 Extended SUT are different from environmentally-extended input-output tables (EE-IOT).[122] EE-IOT can readily incorporate flows of individual ecosystem services following the same methods that would be applied to incorporate flows of, for example, flows of greenhouse gas emissions, water use or solid waste. However, in an EE-IOT there is no inherent change or extension in the SNA production boundary as is applied in the extended SUT and as a result there is no inherent extension of supply chains that record the links between the economy and ecosystems.

[122] The connection between EE-IOT and the SEEA Central Framework accounts is described in the SEEA Applications and Extensions (United Nations et al., 2017).

Table 11.1a: Extended supply and use table with ecosystem services – supply table

Supply	Selected economic units: Selected industries: Agriculture	Forestry	Fisheries	Mining and quarrying	Manufacturing	Electricity, gas, steam and air conditioning supply	Water supply; sewerage, waste management and remediation activities	Services	Other industries	Total Industry				Imports	Total Supply
Products															
Agricultural products															
Forestry products															
Fishery products															
Manufacturing products															
Electricity and gas products															
Water supply products															
Services															
Other products															
TOTAL															
Ecosystems services															
Provisioning services															
Regulating and maintenance services															
Cultural services															
TOTAL															
TOTAL SUPPLY															

Supply	Ecosystem type (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																		Total Supply resident ecosystem assets	Supply from non-resident ecosystem assets - Imports	Total Supply ecosystem services	TOTAL SUPPLY
	Terrestrial												Freshwater			Marine						
	T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1				
	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	...	Temperate pyric sclerophyll forests and woodlands	...	...	...	Derived semi-natural pastures and old fields	Permanent upland streams	...	Intermittently closed and open lakes and lagoons	Seagrass meadows	...	Coastal saltmarshes and reedbeds				
	T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3				
Products																						
Agricultural products																						
Forestry products																						
Fishery products																						
Manufacturing products																						
Electricity and gas products																						
Water supply products																						
Services																						
Other products																						
TOTAL																						
Ecosystems services																						
Provisioning services																						
Regulating and maintenance services																						
Cultural services																						
TOTAL																						
TOTAL SUPPLY																						

NB: Dark grey cells are null by definition

Table 11.1b: Extended supply and use table with ecosystem services – use table

	Selected economic units														
	Selected industries														
Use	Agriculture	Forestry	Fisheries	Mining and quarrying	Manufacturing	Electricity, gas, steam and air conditioning supply	Water supply; sewerage, waste management and remediation activities	Services	Other industries	**Total Industry**	Government consumption	Household consumption	Gross capital formation	Exports	**Total Use**
Selected products															
Agricultural products															
Forestry products															
Fishery products															
Manufacturing products															
Electricity and gas products															
Water supply products															
Services															
Other products															
TOTAL															
Ecosystems services															
Provisioning services															
Regulating and maintenance services															
Cultural services															
TOTAL															
TOTAL USE															
Gross value added															
Compensation of employees															
Gross operating surplus															
Consumption of fixed capital															
Net value added															

	Ecosystem type (based on Level 3 - EFG of the IUCN Global Ecosystem Typology)																					
	Terrestrial												Freshwater			Marine						
	T1 Tropical-subtropical forests				T2 Temperate-boreal forests and woodlands				...		T7		F1	...	FM1	M1	...	MFT1				
	Tropical-subtropical lowland rainforests	Tropical-subtropical dry forests and scrubs	Tropical-subtropical montane rainforests	Tropical heath forests	Boreal and temperate high montane forests and woodlands	Deciduous temperate forests	...	Temperate pyric sclerophyll forests and woodlands	...	...	...	Derived semi-natural pastures and old fields	Permanent upland streams	...	Intermittently closed and open lakes and lagoons	Seagrass meadows	...	Coastal saltmarshes and reedbeds	**Total use resident ecosystem assets**	Exports - ecosystem services	**Total Use ecosystem services**	**TOTAL USE**
Use	T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	...	T2.6	...	...	...	T7.5	F1.1	...	FM1.3	M1.1	...	MFT1.3				
Selected products																						
Agricultural products																						
Forestry products																						
Fishery products																						
Manufacturing products																						
Electricity and gas products																						
Water supply products																						
Services																						
Other products																						
TOTAL																						
Ecosystems services																						
Provisioning services																						
Regulating and maintenance services																						
Cultural services																						
TOTAL																						
TOTAL USE																						

NB: Dark grey cells are null by definition

11.3 Extended balance sheets

11.3.1 Introduction

11.16 Ecosystem accounting data can be used to augment the economic accounts of the SNA through the compilation of extended balance sheets. Extended balance sheets allow the comparison and integration of the values of ecosystem assets with values of produced assets, financial assets (and liabilities), and other assets.

11.17 The development of extended balance sheets aligns with the general intent in the compilation of wealth accounts as has been driven forward by the World Bank[123] and United Nations Environment Programme.[124] In general terms there is a common desire to extend the valuation of natural capital to incorporate a wide range of ecosystem services beyond those that are incorporated in the valuation of natural resources according to the SNA. Where the outputs of wealth accounting apply exchange value concepts in the valuation of different capitals, the values from the monetary ecosystem asset account are appropriate for inclusion in the extended balance sheet described here. Note that wealth accounts may also include measures of human capital (and in some cases social capital) in addition to produced and non-produced (natural) capital and hence go beyond the scope of both the SEEA EA and the SNA.

11.18 Extended balance sheets encompassing monetary values of ecosystem assets can be applied in a number of contexts. These include understanding the changing composition of wealth, identifying imbalances in stocks of wealth, analyzing productivity and assessing returns on investment.

11.19 A concern regarding extensions made to balance sheets containing the monetary values of economic and ecosystem assets is that, by presenting the different assets side by side, it may be interpreted as meaning that all assets are substitutable. In theory, estimates of all asset prices should take into account the extent to which there are developing shortages in the availability of certain "critical" resources, where the effect should be that asset prices reflected in the accounts rise over time, and the relative value of these assets becomes much higher. However, in practice, since the future trends in the availability of various assets and their interactions cannot be well anticipated, the extent to which shortages and imbalances will be reflected in estimated asset prices will be more limited.

11.20 Compiling extended balance sheets involves complementing the opening and closing values of ecosystem assets as described in chapter 10 with SNA balance sheet values described in SNA 2008, chapter 13. In some cases, there may be an overlap between the scope of SNA asset values and the scope of ecosystem assets, for example with regard to the values of biological resources and land. To avoid a double counting of asset values, clear treatments of different assets is required. These treatments are discussed in sub-section 11.3.3.

11.3.2 Structure of an extended balance sheet

11.21 Conceptually, an extension of the SNA balance sheet requires that the values of ecosystem assets over and above those currently recorded in the SNA balance sheets be included. However, since the value of ecosystem assets commonly includes the value of natural

[123] See the World Bank Changing Wealth of Nations project and related outputs (World Bank, 2018). See https://www.worldbank.org/en/news/infographic/2018/01/30/the-changing-wealth-of-nations

[124] See the UNEP Inclusive Wealth (UNEP, 2018). See https://www.unenvironment.org/resources/report/inclusive-wealth-report-2018

resources (such as timber resources) and components of land values, there are a range of ways in which the additional values might be combined and presented.

11.22 The approach adopted here, presented in Table 11.2, is to first distinguish environmental assets from produced assets, other non-produced (non-environmental) assets and financial assets and liabilities. Then, within environmental assets, to distinguish (i) ecosystem asset values linked to each of the ecosystem types at the level of the main realms (terrestrial, freshwater, marine and subterranean); and (ii) values of other environmental assets including land, renewable energy resources, cultivated biological resources, water resources, mineral and energy resources and atmospheric systems.

11.23 The ecosystem asset values will align with those included in the monetary ecosystem asset account (Table 10.1). The values of other environmental assets will generally align with the values in the SNA for the relevant classes taking into account the treatments in the SEEA Central Framework, chapter 5. However, there may be some values of other environmental assets relating to the values of abiotic flows and spatial functions, for example, values relating to renewable energy resources which may be outside the scope of SNA and SEEA Central Framework based valuations. These additional values should be recorded under other environmental assets as appropriate.

11.24 For each ecosystem realm, the total monetary value including all ecosystem services is recorded, thus reflecting an aggregation of the monetary values compiled in the monetary ecosystem asset account. Following the advice in the SNA, the values for other environmental assets will overlap in a number of cases with the values recorded against the various ecosystem types. For example, the value of cultivated land will include an ecosystem asset value. The relevant boundary cases are considered below and conventions are described to support comparable measurement.

11.25 An extended balance sheet would most commonly be compiled at a national level building from a country's national balance sheet from the SNA. Thus, the geographic scope of the extended balance sheet would be defined by the country's economic territory which, in geographic terms is broadly limited to its land area and marine areas within the EEZ. Conceptually, it would be possible to define extended balance sheets for alternative geographic scopes, for example encompassing a wider coverage of marine ecosystems, or focusing on sub-national areas.

Table 11.2: Structure of an extended balance sheet

		Monetary value	
		Opening	Closing
Assets			
Produced assets*	Fixed assets • Dwellings • Other buildings and structure • Machinery and equipment • Weapons systems • Intellectual property products		
	Inventories**		
	Valuables		
Environmental assets - ecosystems	Terrestrial ecosystems (IUCN GET EFG T1-T7) (includes SNA value of natural timber resources, and other non-produced biota)		
	Freshwater ecosystems (IUCN GET EFG F1 – FM1) (includes SNA value of natural aquatic resources, and other non-produced biota) (Excludes the value of water resources)		
	Marine ecosystems (IUCN GET EFG M1-MFT1) (includes SNA value of natural aquatic resources, and other non-produced biota)		
	Subterranean ecosystems (IUCN GET S1-SM1)		
Environmental assets – other	Cultivated biological resources • Fixed assets • Work in progress (inventories)		
	Land (as provision of space) (includes SNA value of Land under buildings)		
	Renewable energy resources**		
	Water resources**		
	Mineral and energy resources		
	Atmospheric systems (includes SNA value of the radio spectrum)		
Other non-produced assets	Contracts, leases and licenses***		
	Goodwill and marketing assets		
Financial assets			
Financial liabilities			
Net worth			

Notes:
* The scope of produced assets presented here is different from the SNA as cultivated biological resources are included under other environmental assets.
** These entries are boundary cases for which specific measurement conventions apply as discussed in section 11.3.3.
*** The value of contracts, leases and licenses concerning environmental assets that satisfy the requirements of the SNA (chapter 17, part 5) to be considered distinct assets are not distinguished in this balance sheet and instead are included in the value of the underlying environmental asset.

11.3.3 Aligning ecosystem asset values with the values of SNA assets

11.26 As highlighted in the previous sub-section, there are a number of potential overlaps between the SEEA measurement scope for ecosystem assets and the SNA measurement scope of economic assets (labelled here "SNA assets"). To articulate the overlaps and differences, the appropriate starting point is the definition of assets in the SNA. The SEEA Central Framework (section 5.2.3) provides a useful overview from an environmental-economic accounting perspective. It notes that,

> *"In the Central Framework, consistent with the SNA, the scope of valuation is limited to the benefits that accrue to economic owners. An economic owner is the institutional unit entitled to claim the benefits associated with the use of an asset in the source of an economic activity by virtue of accepting the associated risks. Further, following the SNA, an asset is a store 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." (SEEA Central Framework, para. 5.32)*

11.27 At an aggregate level, for example for a country, where the aim is to convey information about the total stock of assets and their monetary value, the inclusion of assets in an extended balance sheet is not straightforward. In effect, the aggregate measures assume attribution of the environmental assets to the country of reference. In turn this implies that establishing a total value for environmental assets requires, in the first instance, the identification of a set of benefits. The focus in aligning the scope of valuation for various asset classes is thus on aligning the extended set of benefits with the relevant asset classes. Issues concerning the ownership of ecosystem assets are considered in sub-section 11.3.4.

11.28 The definition of benefits in the SNA is potentially broad in concept, since they *"reflect a gain or positive utility arising from economic production, consumption or accumulation" (2008 SNA, para. 3.19).* However, in practice, the scope of the SNA with respect to benefits from environmental assets is limited to those:

> "*(i) in the form of operating surplus from the sale of natural resources and cultivated biological resources; (ii) in the form of rent earned on permitting the use or extraction of an environmental asset; or (iii) in the form of net receipts (i.e., excluding transaction costs) when an environmental asset (e.g., land) is sold." (SEEA Central Framework, para. 5.33).*

11.29 In ecosystem accounting, a broader set of benefits is included through the recognition of ecosystem services that contribute to non-SNA benefits. The inclusion of the monetary value of ecosystem services that contribute to non-SNA benefits increases the value of environmental assets relative to the SNA and hence extends the balance sheet relative to the scope of the SNA. Nonetheless, the inclusion of these additional monetary values does not provide a measure that encompasses all aspects of value or wealth.

11.30 To clarify the nature of the extensions to the SNA balance sheets due to considerations about the scope of benefits, the following paragraphs describe the treatment of a range of SNA assets with respect to incorporating ecosystem assets. In practice, since relatively few countries compile full SNA balance sheets of non-produced assets, the following considerations, taken in conjunction with advice and treatments in the SEEA Central Framework, will be relevant in developing such balance sheets in the first instance or in refining initial estimates.

11.31 Treatment of biological resources. The value of all natural (non-cultivated) biological resources will be in scope of both ecosystem assets and SNA non-produced assets. Thus, values of natural timber, aquatic and other biological resources (e.g., wild animals and non-wood forest products) will be estimated in terms of the expected future rates of harvest and relevant prices for these provisioning services. In the extended balance sheet, the value of these natural biological resources is included within the relevant ecosystem asset – for example, the value of natural timber resources is included within the broader value of forest ecosystems.

11.32 For cultivated biological resources, related to agriculture, forestry and fisheries, there is a range of types to be considered including annual crops, plantations (e.g., timber, orchards, vineyards), livestock for slaughter, livestock for breeding and ongoing production (e.g., dairy cows, sheep for wool) and aquaculture. These resources, considered to be produced assets, are classified as either inventories (work in progress)[125] or fixed assets. The SNA value for these resources is included in the scope of environmental assets as defined in SEEA Central Framework.

11.33 The values of cultivated biological resources included in the SNA relate only to the stock of those resources that are present on the date of the balance sheet (e.g., it will relate to the number of cattle or volume of standing timber on 31 December). Two separate cases are noted. In the case of crops and livestock, their balance sheet value will be separable from the value of any associated land. Since the value of ecosystem services will reflect the contribution of land to the growth of the crops or livestock, in the extended balance sheet the value of cultivated crops and livestock are recorded as "other environmental assets" separately from the value of the associated ecosystem asset (e.g., pastures, cultivated land) which will encompass the net present value of the expected biomass provisioning services.

11.34 In the case of cultivated timber, the SNA balance sheet value concerns the value of standing timber and is estimated as the discounted *"future proceeds of selling the timber at current prices after deducting the expenses of bringing the timber to maturity"* (2008 SNA, para. 13.41). The expenses should also incorporate capital costs associated with the inputs of produced assets and forest land (see SEEA Central Framework, section 5.8). This value will overlap with the net present value of wood provisioning services although this latter value will be higher since it will include (i) the value of the contribution of the land; and (ii) the value of future timber harvests beyond the current rotation. Consequently, to ensure alignment between the values recorded in the extended balance sheet and the values recorded in the monetary ecosystem asset account, the work-in-progress value of cultivated timber resources should not be recorded as part of other environmental assets.

11.35 <u>Treatment of mineral and energy resources</u>. These natural resources are defined in the SNA and the SEEA Central Framework but are not considered a part of ecosystem assets since the benefits they provide are not the result of current ecosystem processes. These include shallow mineral resources such as sand and gravel. They are recorded in the extended balance sheet under other environmental assets. By convention, this class excludes energy from renewable sources, as discussed in the following paragraphs.

11.36 Special note is made of peat resources which may be used as a form of fossil fuel. Peatlands are also an important type of terrestrial ecosystem supplying a range of ecosystem services, including global climate regulation and water purification services. In this balance sheet, the value of peatlands is partitioned with the value of future flows of ecosystem services included as part of terrestrial ecosystems and the value associated with the use of peat as a fossil fuel resource included as part of mineral and energy resources.

11.37 <u>Treatment of energy from renewable sources</u>. Renewable sources of energy (such as wind and solar sources) cannot be exhausted in a manner akin to fossil energy resources and

[125] Work in progress on cultivated biological resources consists of output that is not yet sufficiently mature to be in a state in which it is normally supplied to other institutional units (2008 SNA, para. 10.140)

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.

11.38 The monetary value associated with the ongoing capture of energy from wind and solar sources can be considered to be embedded in the values of the associated area (e.g., land), reflecting the specific characteristics of the location in which the renewable energy is captured. In the extended balance sheet, by convention, the value of location (including both terrestrial and marine locations) that is linked to the capture of, for example, wind and solar energy, should be included in the value of land (as provision of space).

11.39 For energy generated through hydroelectric power generation, the monetary value associated with the capture of energy can also be considered as embedded in the values of the surrounding area that will incorporate water resources and land formations. For energy generated from geothermal resources, relevant values should be included under deep geological systems. It is recommended to separately record the value associated with the energy from renewable sources in the extended balance sheet, calculated using the NPV of the associated abiotic flows.

11.40 Treatment of inland water resources (i.e., excluding marine ecosystems). The valuation of water resources is recognized in the SNA in cases where *"surface and groundwater resources used for extraction to the extent that their scarcity leads to the enforcement of ownership or use rights, market valuation and some measure of economic control" (2008 SNA, para. 10.184).* It is recommended that this value should be recorded separately from the value of ecosystem services of freshwater ecosystems.

11.41 The value of water supply is treated as an abiotic flow and hence is recorded as part of other environmental assets – as water resources - rather than associated with the terrestrial or freshwater ecosystem asset to which they are most directly connected (e.g., based on the location of a bore or well). In this context, the value of water resources is limited to its use as input to economic activity and human consumption. It is noted that the valuation of water is a challenging area of measurement and an alignment of methods and scope based on advice from the SNA, the SEEA Central Framework and the SEEA EA will be required.

11.42 Treatment of land. A key function of land is to provide space. Land, and the space it represents, define the locations within which economic and other activity is undertaken and within which assets are situated. This role of land is a fundamental input to economic activity and has significant value in many locations.

11.43 However, the provision of space is not considered as an ecosystem service and consequently the value of ecosystem assets, particularly terrestrial ecosystems, excludes the value of the provision of space. Thus, depending on the location and ecosystem type, the total value of an area of land may be greater than the value of the aggregated ecosystem services. Particularly note is made of urban ecosystems and cultivated land. For urban ecosystems, the value of the provision of space may be the predominant component of the total value of environmental assets. For cultivated land the distinction may be less evident, i.e., the value of provisioning ecosystem services may be closer to the total market value of the land as recorded in the SNA. However, the value of the ecosystem asset as a whole may be larger than the SNA based land value, through the inclusion of the value of non-provisioning services (e.g., water regulation) which are supplied by cultivated land but are not recognized in the market value of land. For areas of government-owned or public land, it is likely that no value is recorded following the SNA and in this case the value associated with the relevant ecosystem assets will reflect the total value of the area for accounting purposes.

11.44 In the extended balance sheet, recognising that values of land will likely differ from the value of ecosystem assets, the approach taken is to record the aggregated net present value of ecosystem services following the advice in chapter 10 against the relevant ecosystem type and then where relevant, record the additional value of land in terms of the provision of space as a separate asset class under other environmental assets. In a number of cases, most notably for urban ecosystems and cultivated land, it will be necessary to partition the value of land as recorded in the SNA to extract that component of value that is attributable to ecosystem services (e.g., in relation to amenity services embodied in land values).

11.45 Treatment of the atmosphere and high seas: The scope of ecosystem assets excludes the atmosphere, and for national level accounting purposes, generally marine areas beyond the EEZ would also be outside the ecosystem accounting area that defines the scope of the extended balance sheet. The values of these environmental assets will therefore not be captured in the value of ecosystem assets. SNA values relevant to these environmental assets include the radio spectrum and fish stocks on the high seas over which ownership rights may exist. The value of the radio spectrum (as defined in the SNA) should be included under atmospheric systems in Table 11.2 and the value of fish stocks on the high seas that satisfy the definition of economic assets in the SNA should be included under marine ecosystems.

11.46 As noted in the previous section, an alternative scope for an extended balance sheet that incorporates a wider range of ecosystem assets such as marine areas beyond the EEZ and the atmosphere could be compiled. Such accounts could recognise the important functions of these ecosystems, for example the role of the ozone layer, and the role of marine ecosystems in regulating global climate.

11.47 Treatment of permits and licenses to use natural resources. In the SNA, the value of permits and licenses associated with the use of natural resources, including for example resource leases and transferable quotas, is recorded separately from the value of the underlying resource. In recording this value separately, the total value of the natural resource is considered to be partitioned with the value of the permit or license reducing the value of the resource that is recorded as part of natural resources. In the extended balance sheet, by convention, the total value of the natural resource is recorded as part of environmental assets and, if required, the value of the associated permit or license, should be recorded as an 'of which' item.

11.4 Assigning economic ownership and allocation of degradation and enhancement

11.4.1 Considerations in assigning economic ownership

11.48 The compilation of the ecosystem accounts in physical and monetary terms does not necessarily require a statement or assumption concerning the ownership of ecosystem assets. This is important since it highlights that accounting for ecosystem assets, their services and their links to the economy can be undertaken from the perspective of ecosystems being distinct ecological entities. This neutrality with respect to ownership enables the set of ecosystem accounts to support a wide range of decision-making contexts.

11.49 This perspective on ecosystem assets is consistent with the wider definition of environmental assets from the SEEA Central Framework in which environmental assets are defined with respect to the components of the biophysical environment and the potential delivery of benefits (SEEA Central Framework, para. 2.17).

11.50 Nonetheless, understanding the legal and economic ownership context of ecosystem assets is of high relevance in developing, enacting and monitoring policy with respect to ecosystem management and use. There is thus a clear policy relevance in cross-classifying data from the ecosystem accounts with data on legal and economic ownership. For example, data from ecosystem extent accounts may be cross-classified with data from cadastres to assess the connections between different ecosystem types and the types of economic units that manage them. Another example is the cross-classification of data on the supply of ecosystem services with data on economic ownership of land and other areas. Undertaking this type of work using spatial data is likely to also be of significant benefit in applying the results from the ecosystem accounts.

11.51 From a national accounting perspective, integration of the ecosystem accounts with the institutional sector accounts of the SNA requires a treatment or appropriate convention to be applied such that the relationship between ecosystem assets and economic units can be consistently recorded. Of particular focus for SEEA EA is integration with the income, distribution of income, capital and financial accounts of the SNA which are structured by institutional sectors and sub-sectors, including corporations, households and general government. To support integration with these accounts and also to underpin derivation of degradation adjusted measures of income and saving, ecosystem assets must be assigned to an institutional sector.

11.4.2 The institutional sector for ecosystem assets

11.52 In the SNA, the discussion and determination of ownership distinguishes between legal and economic ownership. The SNA defines the legal owner as "*the institutional unit entitled in law and sustainable under the law to claim the benefits associated with the entities"* (2008 SNA, para. 10.5) Entities include goods and services, financial assets, natural resources, etc. The economic owner is *"the institutional unit entitled to claim the benefits associated with the use of the entity in question in the course of an economic activity by virtue of accepting the associated risks"* (2008 SNA, para. 10.5).

11.53 Further, all buildings and structures and almost all land and marine areas within the economic territory of a country are deemed, by convention, to be owned by economic units that are considered resident in that territory.[126] Where a non-resident unit is the legal owner, a notional resident unit is created which is considered to own the relevant asset, and the non-resident unit then holds a financial asset equal to the value of the notional resident unit. This treatment underpins the recording of flows between ecosystem assets and economic units that are resident in the rest of the world, including with respect to imports and exports of ecosystem services and the attribution of value in a balance sheet context.

11.54 In many cases, the legal and economic owner are the same, but there are a range of situations in which there may be a lack of clarity. Such situations include government ownership of entities, such as public roads, national parks, natural resources; situations involving financial leases; and assets built under private finance initiatives. In these contexts, measurement approaches may be supported through use of the definitions in the Framework on Effective Land Administration.[127]

11.55 Using these national accounting principles of economic ownership which are founded on the relationship to between an institutional unit and the benefits from an asset (or entity), and solely for the purpose of integrating ecosystem accounts data with the standard sector

[126] A small exception applies to the treatment of land and buildings of foreign governments such as embassies which are treated as outside the economic territory of a country. This matter is not considered material to the development of integrated environmental-economic accounts and hence is not considered further here. As required, the treatments in the 2008 SNA should be applied.

[127] United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM), May2020 (E/C.20/2020/29/Add.2): https://ggim.un.org/meetings/GGIM-committee/10th-Session/documents/E-C.20-2020-29-Add_2-Framework-for-Effective-Land-Administration.pdf

accounts of the SNA, it is considered appropriate to partition the ownership of ecosystem assets using a focus on the users of different types of ecosystem services. In effect, this represents a partitioning of the benefits rather than a partitioning of the ecosystem asset in physical terms. Thus, where an ecosystem asset supplies ecosystem services that contribute to SNA benefits (i.e., primarily provisioning services), that part of the value of the asset will be considered to be owned by the sector that uses those ecosystem services. Most commonly, this will be the legal and economic owner of the land who is using the ecosystem services as inputs to private returns (e.g., in agriculture and forestry).

11.56 At the same time, where an ecosystem asset supplies ecosystem services that contribute to non-SNA benefits (i.e., primarily regulating and maintenance services and cultural services), that part of the value of the asset will be considered to be owned by a new sub-sector of general government titled the "ecosystem trustee". In this treatment, the ecosystem trustee operates analogously to other institutional units, both receiving benefits through the supply of ecosystem services and incurring costs in relation to the supply of those services. The ecosystem trustee is therefore not equivalent to the ecosystem asset.

11.57 In the situation where an ecosystem asset does not contribute to non-SNA benefits, the treatment will align with the assignment of ownership in the SNA. Where an ecosystem asset does not contribute to any SNA benefits, the ecosystem trustee is assigned complete ownership. This situation may arise in remote areas of a country. Commonly, there will be some partitioning of ownership recognising that many ecosystem assets will contribute to both SNA and non-SNA benefits. Note that there are areas that are commonly owned (e.g., for grazing livestock) or are under government or public sector ownership and which contribute to SNA benefits. In these cases, ownership is not assigned solely to the ecosystem trustee but to the economic units deemed to own those benefits following the approach just described.

11.58 This approach to the allocation of ownership allows the resulting institutional accounts to align most closely to the existing understanding of the economic and financial situation of the current SNA institutional sectors. The main differences concern the recognition of the use of ecosystem services as inputs to their production of SNA benefits and recognition of any costs of ecosystem degradation associated with that use of those services.

11.59 Two alternative ownership allocation assumptions might be applied in which (i) all ecosystem assets are assigned to an ecosystem trustee; or (ii) all ecosystem assets are assigned to relevant economic units. While accounting entries and sequences of accounts can be developed under either of these assumptions, the partitioned asset approach aligns most closely to the accounting principles inherent in the SNA. Although the economy wide measures of aggregates such as gross value added and degradation adjusted value added are unaffected by the approach taken to assigning ownership, different ownership assumptions will impact the relative sizes of these aggregates at the institutional sector level. La Notte & Marques (2019) consider the effects of different approaches.

11.4.3 Allocation of degradation and enhancement to economic units

11.60 Chapter 10 described approaches to the valuation of ecosystem degradation and enhancement in the context of the monetary ecosystem asset account. In that account, the focus of measurement is on degradation and enhancement for individual ecosystem assets and ecosystem types within an ecosystem accounting area.

11.61 When integrating ecosystem accounts with economic accounts, the allocation of ecosystem degradation and enhancement to economic units is required. For both degradation and enhancement, this allocation is directly related to the approach applied to assigning ownership as explained above. Thus, ecosystem degradation and enhancement of an ecosystem asset is partitioned and recorded in the accounts of either the economic unit that receives the SNA benefits or the new ecosystem trustee in relation to contributions to non-SNA benefits.

11.62 For integrated economic accounting in the SEEA, a costs borne approach for recording ecosystem degradation is followed meaning that the cost of capital is attributed to the economic unit who is assigned ownership of the asset. This is consistent with general accounting practice. An alternative is to allocate degradation on the basis of costs caused (polluter pays) by determining the appropriate “source”, i.e., the economic unit that has caused the degradation. This may be challenging, for example due to factors of distance (i.e., when impacts of causing economic units are felt in distant ecosystems) and time (i.e., when the impacts become evident well after the causing activity occurred). Nonetheless, it is recognized that there is likely to be substantial policy interest in providing estimates of an allocation of degradation that is attributable to causing or polluting economic units. Chapter 12 includes discussion of the presentation of such complementary estimates. It is noted that the aggregate measure of degradation from the ecosystem accounts is not affected by the choice of allocation approach.

11.5 Integrated sequence of institutional sector accounts

11.5.1 Introduction

11.63 As introduced in the previous section, ecosystem accounting data can be used to augment the economic accounts of the SNA through the compilation of an extended sequence of accounts for institutional sectors. The extended sequence of accounts shows how entries for the values of ecosystem services, and changes in ecosystem assets (including ecosystem degradation and enhancement) can be combined with standard measures of production, income and consumption, and associated accounting aggregates such as saving and net lending.

11.64 One of the main functions of the sequence of accounts is to demonstrate the linkages among incomes, investments and balance sheets. In this regard, a key feature of the standard SNA sequence of accounts is the attribution of consumption of fixed capital (depreciation) to economic activities and institutional sectors as a cost against income. The equivalent outcome from an extended sequence of accounts is the attribution of ecosystem degradation as a cost against the income of institutional sectors. Thus, the extended sequence of accounts describes the relevant accounting entries for the derivation of adjusted measures of value added, domestic product, national income and net worth. Section 11.5.3 describes adjusted income measures.

11.5.2 Structure of the extended sequence of accounts

11.65 The design of an extended sequence of accounts reflects the ownership structure described in section 11.4. The extension thus requires the inclusion of the ecosystem trustee as a new sub-sector within, or next to, the general government sector.

11.66 This extended sequence of accounts is shown in Table 11.3 where a simple example is used to show the different accounting entries. The example shows a simplified economy consisting of a farm that produces wheat (with an output value of 200). The wheat is purchased and consumed by households. The cropland used by the farmer provides a mix of ecosystem services (gross ecosystem services supply of 110) of which 80 are used by the farmer as input to wheat production (i.e., crop provisioning services as inputs to SNA benefits) and 30 are recreation-related services which are inputs to the non-SNA benefit of physical and mental health. For simplicity, all production of the farmer (200) is recorded as final consumption of households and no other production, intermediate consumption or final consumption is recorded. Furthermore, it is assumed that compensation of employees is 50, and that the consumption of fixed capital of a tractor by the farmer is 10.

11.67 For the purpose of comparison, the accounting entries following the recording principles of the standard SNA are also shown. In this case, no transactions in ecosystem services are recorded as this activity lies outside the production boundary. Following the SNA, the economy in this example has a value added (GDP) of 200 and the farmer has a net saving of 140.

11.68 Following the partitioned ownership approach described in section 11.4, the ecosystem asset is partitioned such that flows of ecosystem services are shown (i) as supplied by farmers in the case of the crop provisioning services (thus increasing the measure of gross output of the farmer); and (ii) as supplied by the ecosystem trustee in the case of recreation-related services. The crop provisioning services are immediately deducted in the accounts of the farmer as intermediate consumption.

11.69 The use of the recreation-related services is shown in two steps. In the allocation/use of income accounts an ecosystem services transfer in kind is recorded as payable by the ecosystem trustee and receivable by the subsequent recipient. In this example, the final recipient of recreation-related services is the household sector but, in other cases, multiple recipients may be recorded. In a second step, the use of the ecosystem services is shown as the final consumption of the household sector.

11.70 As noted in section 11.4.2, the ecosystem trustee is a sub-sector related to general government that is regarded as managing the flow of ecosystem services contributing to non-SNA benefits. While the ecosystem asset itself does not incur costs, there may be expenditure undertaken to manage the ecosystem asset to supply the services. In the institutional sector accounts, these costs should be recorded as the intermediate consumption or capital formation of the ecosystem trustee. This will involve reallocating expenditures from other institutional sectors.

Table 11.3: Models for including ecosystem services in the sequence of accounts (excluding financial account and change in balance sheet entries) (currency units)

			SNA treatment			Extended sequence of accounts			
			Sector		Total	Sector			Total
			Agri.	Household		Agri.	Household	Ecosystem trustee	
Production and generation of income acccount									
	Output	Products (wheat)	200		200	200			200
		Ecosystem services (crop provisioning)				80			80
		Ecosystem services (recreation)						30	30
	Total output		200		200	280		30	310
	Intermediate consumption	Products	0		0	0		0	0
		Ecosystem services (crop provisioning)				80		0	80
	Gross value added		200		200	200		30	230
	less Consumption of fixed capital (produced assets)		10		10	10		0	10
	less Ecosystem degradation					10		5	15
	Degradation adjusted net value added		190		190	180		25	205
	less Compensation of employees		50		50	50		0	50
	Degradation adjusted net operating surplus		140		140	130		25	155
Allocation / Use of income accounts									
	Degradation adjusted net operating surplus		140		140	130		25	155
	plus Compensation of employees			50	50		50		50
	Ecosystem service transfer in kind payable							30	30
	Ecosystem services transfer in kind receivable						30		30
	Degradation adjusted disposable income		140	50	190	130	80	-5	205
	less Final consumption	Products (wheat)		200	200		200		200
		Ecosystem services (recreation)					30		30
	Degradation adjusted net saving		140	-150	-10	130	-150	-5	-25
Capital account									
	Degradation adjusted net saving		140	-150	-10	130	-150	-5	-25
	plus Consumption of fixed capital (produced assets)		10		10	10			10
	plus Ecosystem degradation					10		5	15
	Net lending/borrowing		150	-150	0	150	-150	0	0

11.5.3 Adjusted income aggregates

11.71 A key focus in the development of the extended sequence of accounts is the derivation of various measures of economic activity including valued added, operating surplus, disposable income and net saving which take into account the cost of ecosystem degradation. Table 11.3 shows how these measures are derived and the relationships between them. Importantly, to retain accounting consistency, in addition to deducting measures of ecosystem degradation, it is necessary that the income measures themselves are extended to incorporate the generation and use of ecosystem services (i.e., the flows that are not captured within the standard SNA production boundary).

11.72 Similar considerations apply to incorporating the effects of changes in ecosystem asset values other than ecosystem degradation, such as ecosystem enhancement and ecosystem conversion. However, the accounting entries required for these other changes in the value of ecosystem assets require further investigation and will be considered as part of the research agenda of the SEEA EA.

11.73 The discussion of adjusting measures of GDP and other SNA aggregates for environmental factors is much broader than the degradation adjusted measures just described. Some considerations on the theoretical relationship between national accounts and welfare are relevant as discussed in annex 12.1. There is also a range of approaches to measurement coverage and valuation that have led to development of a variety of alternative and complementary measures of the environment-economy relationship. Chapter 12 provides an overview of the approaches and the relationship to the measures described in the ecosystem accounts and in the extended accounts presented in this chapter.

Annex 11.1: Example of an extended supply and use table

A11.1 Table 11.4 shows a small, stylized series of supply and use tables (SUT) using timber production as an example. Part A of the table presents the standard SUT recording of timber production for furniture purchased by households, i.e., no ecosystem services are recorded. It shows the output of logged timber by the forestry industry (50 units), the use of that timber by the manufacturing industry, and the ultimate sale of the furniture to households of 80 units. Total value added of 80 is recorded equal to both the sum of the value added for forestry and manufacturing and the total household final consumption expenditure.[128]

A11.2 Part B extends this recording to include the flow of wood provisioning services (30 units) from the ecosystem asset (a forest) which is recorded as an input to the forestry industry. There is thus an additional row and an additional column in the SUT relative to the standard SUT in Part A. The main effect of this extension is to partition the value added of the forestry industry between the industry (previously 50, now 20) and the ecosystem asset (now 30, equal to the supply of ecosystem services). Overall, value added through the inclusion of the ecosystem asset remains unchanged (at 80 currency units) even though the total supply for all units has increased by 30. This reflects the extension of the production boundary.

A11.3 Part C introduces a second ecosystem service, air filtration, which is supplied by the same ecosystem asset (i.e., the forest). In this case, a second additional row is required but no additional columns. Total supply is further increased (by 15 units), but in this case, total value added also rises (to 95 units) because the additional output is not an input to existing products. Rather, the supply of air filtration services is recorded as an increase in the final consumption of households.

A11.4 An important result of integrating the flows of ecosystem services in the extended SUT is that it becomes clear how the commonly discussed topic of double counting can be managed. Quite commonly, there is concern that integrating ecosystem services with the national accounts will result in double counting (in terms of the impacts on value added and GDP) if the final ecosystem services that contribute to SNA benefits are recorded. The gross basis of recording – i.e., recording both supply and use of ecosystem services - that is applied in both Table 11.1 and Table 11.4 is the most transparent means of dealing with double counting.

[128] The recording presented here ignores all other inputs and potentially relevant flows (e.g., labour costs, retail margins, taxes, etc.).

Table 11.4: Stylized example of an extended SUT (currency units)

	Ecosystem asset (forest)	Forestry industry	Manufacturing industry	Household final demand	Total
PART A: Standard SUT					
Supply					
Logged timber		50			50
Furniture			80		80
Use					
Logged timber			50		50
Furniture				80	80
Value added (supply less use)		50	30		80
PART B: Extended SUT (SNA benefits)					
Supply					
Ecosystem service – wood provisioning	30				30
Logged timber		50			50
Furniture			80		80
Use					
Ecosystem service – wood provisioning		30			30
Logged timber			50		50
Furniture				80	80
Value added (supply less use)	30	20	30		80
PART C: Extended SUT (non-SNA benefits)					
Supply					
Ecosystem service – wood provisioning	30				30
Ecosystem service – air filtration	15				15
Logged timber		50			50
Furniture			80		80
Use					
Ecosystem service – wood provisioning		30			30
Ecosystem service – air filtration				15	15
Logged timber			50		50
Furniture				80	80
Value added (supply less use)	45	20	30		95

SECTION E: Applications and extensions of SEEA EA

Section overview

Section E comprising chapters 12 – 14 describes applications and extensions of the SEEA EA. It has been drafted to support a shared understanding among compilers and users of the how data from the various ecosystem accounts may be applied to support analysis and decision-making.

Three different areas of application and extension are covered in this section. The first covers complementary approaches to valuation. The measurement of monetary values based on exchange values as described in chapters 8 – 11 supports comparison with the accounting values of the national accounts and a range of other uses described in chapters 8-11. However, there are limits to the range of economic values included in these measures and there are a number of applications which exchange based values cannot support directly. The discussion in chapter 12 recognizes that there are other approaches to monetary valuation and a number of other valuation concepts, such as welfare values and total economic values, that have been extensively used in decision making such as for cost-benefit analysis, scenario assessments or the development of environmental markets.

Describing these complementary approaches to valuation aims to support account compilers understand the different ways in which valuation may be considered and how the compilation of ecosystem accounts relates. Further, for users of the accounts, this discussion is intended to place various valuation approaches in the context and hence clarify the potential of ecosystem accounts to support analysis and decision making. A body of research on complementary approaches to accounting for the environment is also emerging, for example the work advancing the complementary accounts network (Badura, Ferrini, & Turner, 2020; Turner et al., 2019). Developing and enriching the relationship among different measurement approaches will support the supply of coherent data and underpin support for decision makers.

More broadly, the compilation of ecosystem accounts is of merit only when the data can be used to support analysis and monitoring of policy and decision making. In this context, chapter 13 describes the potential to use SEEA EA and other data, including data from the accounts of the SEEA Central Framework and the SNA, to support discussion of individual policy themes. Four high-profile environmental themes are considered – biodiversity, climate change, oceans and urban areas – but the approach can also be applied in other contexts. The discussion in chapter 13 also highlights that accounting approaches can be used to organise data on specific variables, such as on species and carbon, to both support the compilation of ecosystem accounts and to better describe the relationship between those variables and economic and human activity.

For monitoring purposes, the most common approach is the use of indicators. Chapter 14 describes how accounting principles can be used to underpin the derivation of more coherent indicators, particularly where data are combined across the economic and environmental domains. There is a range of indicator initiatives at local, national and global scales and across various ecosystem realms. The chapter provides an introduction to the potential role of the SEEA and ecosystem accounting for these initiatives, with particular note of the links to reporting on the 2030 Agenda for Sustainable Development and the Post-2020 Global Biodiversity Framework.

12 Complementary approaches to valuation

12.1 Introduction

12.1 The primary purpose of ecosystem accounting is to integrate information on ecosystems with measures of economic activity. To align with SNA principles, the ecosystem accounts in monetary terms as described in chapters 8-11, record entries based on the exchange value concept. While this approach supports alignment with the accounting values of the national accounts, and hence with macro-economic policy, there are other monetary approaches and valuation concepts involving welfare values, willingness to pay and total economic values that have been extensively used in other decision-making contexts such as for cost-benefit analysis or project appraisal.

12.2 The alignment with SNA principles in the SEEA EA also implies that the monetary values recorded in the ecosystem accounts reflect the current use of ecosystems. Thus, they are based the existing management regimes and institutional arrangements, regardless of whether the associated patterns of use may be considered (un)sustainable or (in)efficient. However, in many contexts it is important to assess scenarios reflecting alternative management regimes or institutional arrangements for ecosystems. For example, it may be relevant to analyze how certain negative externalities (e.g., pollution) might best be internalized in the decisions of economic units. The monetary values of the ecosystem accounts supports, but does not incorporate, such alternative valuations.

12.3 In this context, this chapter considers how the monetary ecosystem accounts presented in chapters 8-11 can be related to, and support, other approaches and applications in monetary terms. Section 12.2 describes a set of complementary tables that can be obtained when taking a welfare-based approach to valuation, and explains the links between these approaches and the ecosystem accounts. Section 12.3 describes alternative measures of income, wealth and degradation that can be derived when making different assumptions regarding the attribution of costs or the institutional arrangements underlying valuation. Section 12.4 describes linkages with corporate assessments of natural capital. Finally, annex 12.1 describes the conceptual connection between exchange and welfare values.

12.2 Building connections with welfare values

12.2.1 Introduction

12.4 The relationship between measures of national income and social welfare has long been a discussion point among prominent economists.[129] Some economists, such as Pigou and Hicks sought to relate observed market values to the framework of utility theory but this approach proved difficult (see Hicks (1975)). An alternative approach, following Kuznets, considered the final objectives of economic activity and hence looked to adjusted measures of aggregate economic activity, most commonly GDP. This approach was pioneered by Nordhaus & Tobin (1972) reflected in their macro-economic welfare index. However, application of this approach has proved challenging due to the difficulties of selecting and measuring the range of possible adjustments for all aspects of social welfare, as demonstrated by the range of alternative indicators that have been proposed subsequently.

[129] See for example the summaries in Obst et al. (2016) and Vanoli (2005).

12.5 In light of these integration challenges, the 2008 SNA that warns against a welfare interpretation of the accounts. It notes that "*GDP is often taken as a measure of welfare, but the SNA makes no claim that this is so and indeed there are several conventions in the SNA that argue against the welfare interpretation of the accounts*" (2008 SNA, para. 1.75). Indeed, it is clarified that the main objective of the SNA is to *"compile measures of economic activity in accordance with strict accounting conventions based on economic principles."* (2008 SNA, para. 1.1). This is not to say that connections do not exist between entries in the national accounts and measures of welfare. This topic is discussed in more detail in annex 12.1.

12.6 The development of SEEA has also frequently touched upon its relationship with welfare measures, mostly in the context of assessing the cost of degradation which, when estimated, would provide the means to adjust GDP and other national accounts measures of income and wealth along the lines initiated by Nordhaus and Tobin. For instance, the SEEA 1993 contained various extensions including one in which the repercussion costs of households of a deteriorated environment would be assessed using contingent valuation. The SEEA 2003 contains both cost-based and damage-based methods for assessing degradation, concluding that adjusting macro-aggregates for the latter "*is the furthest removed from the normal SNA conventions and impinges on the realm of welfare measurement*" (SEEA 2003, para. 1.96)

12.7 The approach taken in the SEEA EA (as explained in chapter 8) is to align the ecosystem accounts with the valuation basis of the SNA. In this section, complementary tables are discussed that support welfare analysis, namely a bridge table linking accounting values to welfare values, and tables that make negative externalities and ecosystem disservices visible.

12.2.2 Bridge table between accounting and welfare values

12.8 To support understanding the links between accounting and welfare values in the context of ecosystem services, the following bridge table, Table 12.1, can be compiled. The table lists the various additions/subtraction to be made in moving from one value concept to the other, for selected ecosystem services. The table also serves to illustrate why accounting values are smaller than welfare-based values.

Table 12.1: Bridge table between accounting and welfare value of ecosystem services (currency units)

	Crop provisioning services	Recreation-related services	Total flow	Asset
1. Accounting value	*10*	*5*	*15*	300
2. Consumer surplus	*0*	*20*		
3. Welfare use-value	*10*	*25*	*35*	700
4. Welfare non-use value				300
Total welfare value				1000

12.9 In the example given, the following assumptions are made:

- An area of land provides crop provisioning services (of 10) to a farmer in the production of crops. This value is derived net of input costs such as labour, fuel, etc.
- The same land area also offers some recreation opportunities for people living nearby. There is no charge for using the area, but individuals must travel some distance to get to it. The valuation methods described in chapter 9 can be used to estimate the accounting value of the recreation-related services (of 5). However, the users of the recreation site obtain a consumer surplus as they would be willing to pay more. This

amount is assumed to be 20. This provides a total welfare-use value of 25 for recreation related services.

- In addition, other people who do not visit the site have a non-use value for it (300). This value is not an individual ecosystem service and is attributed to the ecosystem asset as a whole.
- Asset values are the net present values of the value of a constant flow of services over an indefinite future at as assumed discount rate of 5%. No changes in prices of inputs or outputs are expected. The corresponding asset values are: (i) 300 based on accounting values – this is the value that would be included in the extended SNA balance sheet (chapter 11), (ii) 700 when based on welfare use values and (iii) 1,000 based on use and non-use values. The latter value would be the value that would be included when compiling wealth accounts on a welfare basis.

12.10 The table highlights some differences between accounting values and welfare values. In addition, it is noted that welfare values are sometimes estimated for benefits rather than the ecosystem contribution to the benefit. In this example, the benefit would be valued using the market price of the crop when sold by the farmer.

12.11 For certain applications, the difference in values between accounting and welfare-based valuations may provide relevant information about so-called *unrealized values*. These may be obtained when comparing the current situation to a situation with changed economic institutions or management regimes for ecosystem assets. For instance, the current management of an ecosystem may result in low exchange values (e.g., an open access ecosystem), whereas the welfare value (elicited by the willingness to pay (WTP) by people for the same ecosystem services) may be very high. Large unrealized values may provide a rationale for policy intervention.

12.12 From a measurement perspective, in order to populate the table, for provisioning and (most) of the regulating and maintenance services, it may be reasonable to assume that no consumer surplus exists. This assumes the final consumer would only be willing to pay the final price (say of the crops) and nothing more. For cultural services, the non-market valuation techniques applied (as described in chapter 9) are commonly used to estimate welfare values. Non-use values (which can be very significant) need to be assessed using stated preference approaches.

12.2.3 Assessing externalities, ecosystem disservices and health outcomes

12.13 Externalities are perhaps the most commonly discussed framing for examining the link between the environment and the economy. Frequently, there is a call for frameworks and information that allows decision makers to “internalise environmental externalities”. This is a general demand to ensure that the negative impacts of business, government and people on the environment are taken in account.

12.14 ***Externalities are impacts that “arise when the actions of an individual, firm or community affect the welfare of other individuals, firms or communities [and the] agent responsible for the action does not take full account of the effect”*** (Markandya et al., 2001). Externalities may be both positive or negative, although much focus in environmental economics is on negative externalities, such as the effects of pollution or emissions. They are measured in terms of the social costs and benefits on other economic units.

12.15 Accounting approaches explicitly do not account for externalities, at least not directly. Accounting, as a transaction-based system, focuses on recording exchanges between units. In contrast, and as discussed in section 6.3.5, the measurement of externalities considers the magnitude of effects which are not exchanges but rather outcomes that arise as a consequence of other activities. In effect, accounting is designed to record trends in stocks and flows as they are – i.e., in the world with the externality. Indeed, the estimates recorded in the accounts will reveal any actual costs or changes in income that may be associated with externalities, such as increased costs incurred with respect to pollution.

12.16 A common focus of externality assessment is cost-benefit analysis wherein there is measurement of the expected effects, both positive and negative, of a particular project, activity or policy change. The analysis, when undertaken for decisions in the public sphere, requires a comparison of the wider social costs and benefits of a given project, activity, or policy.

12.17 From a measurement perspective, a key feature of assessing externalities is the assessment of the effect on welfare arising from the specific activities. In this analysis, welfare is generally measured in terms of effects on consumer and producer surplus. Thus, negative externalities have a negative effect on the total surplus of other economic units. As discussed in annex 12.1, there are conceptual links between measures of welfare based on total surplus and the exchange values recorded in accounting, but the concepts of value are not equivalent.

12.18 While the analytical framing and the valuation concept is different in externality assessments, ecosystem accounting information can provide inputs to the assessments through its recording of changes in ecosystem condition and changes in ecosystem services flows that arise as a result of a particular activity (e.g., impacts of the use of fertiliser and pesticides on water bodies and biodiversity). Thus, the accounts can provide baseline information for the derivation of total surplus measures.

12.19 Positive externalities. With respect to positive externalities, a conceptually simple extension to the ecosystem services flow account in monetary terms is to value the flows of services in terms of their total surplus, i.e., producer plus consumer surplus, rather than using exchanges values as described in Chapter 9. For example, the exchange value of pollination services can be identified through analysis of market values of pollinated agricultural outputs while the full economic value of pollination, potentially measured in the context of a change in the pollinator population, can be measured in welfare terms. These complementary valuations may be presented alongside estimates in exchange value terms. The bridge table shown in Table 12.1 is an example of this application.

12.20 Negative externalities and ecosystem disservices. While the accounts do not directly adjust or measure negative externalities as a distinct concept, the data in any set of accounts will track the effects of externalities over time, to the extent that the effects are within the prescribed accounting boundaries. Further, it will be possible to record the effects, for example, on ecosystem condition and changes in flows of ecosystem services, for individual ecosystem assets. In addition, in the related economic accounts, additional costs incurred by affected economic units will be recorded and changed patterns of income of affected economic units will be able to be assessed. Finally, the accounts will record the net effect of any mitigation action that is undertaken by the economic unit that generates the externality – i.e., to the extent that mitigation action occurs, the effects on ecosystem condition, services, costs and revenue will likely be lower.

12.21 By way of example, additional costs associated with water purification resulting from excess fertiliser use will be recorded in the accounts of the water supply and distribution company; and degradation in soil quality through over-cropping will be reflected in reduced ecosystem condition and reduced output of an affected farmer.

12.22 The primary differences between the estimates recorded in accounts and those measured using an externalities framing are that (i) the accounts themselves to do not record the reason for the changes in ecosystem condition, the value of output of the sectors or associated attribution of costs; and (ii) the accounts do not aim to measure what might have happened under an alternative set of circumstances. At the same time, it is clear that the data from the accounts can underpin such assessments and, in particular, can be used to associate externalities to specific locations and affected ecosystem assets.

12.23 Ecosystem disservices fall into a similar category as negative externalities in that there are negative effects on people and economic units. A useful distinguishing feature is that disservices may be characterised as being caused by environmental factors (e.g., mosquitoes causing malaria), whereas negative externalities are caused by the activities of economic units (e.g., land clearing spreading zoonotic diseases). The appropriate framing of disservices from an accounting point of view, as described in section 6.3.5, is to capture the wider effects of ecosystem disservices implicitly as a reduction in the flows of ecosystem services (e.g., pests destroying crops and reducing biomass provisioning services; algal bloom reducing the opportunities for recreational activities in lakes).

12.24 The following tables demonstrate the potential to provide alternative recordings (using an accounting structure) that highlight ecosystem disservices and negative externalities. Table 12.2 illustrates how a disservice can be recorded. Suppose we have an economy in which there are two activities: ISIC A – Agriculture and ISIC C - Manufacturing, producing respectively two products X (crops) and Y (canned goods). In addition, assume that an ecosystem service A is being provided to ISIC A. Further, suppose a disservice B is introduced – an example is of elephants trampling agricultural produce and thus reducing the output of crops.

12.25 Table 12.2 recognizes both the ecosystem services of biomass provisioning and the disservice. The disservice effectively causes a reduction of 20 in the value of the ecosystem service, which is why it is introduced as a negative. Now the net value of the crop provisioning service is 50, which is used by ISIC A. An income transfer is also recorded such that the same disposable income is recorded as in the situation without the recording of the disservice (as in the SNA). The advantage of this table compared to the extended supply and use table (Table 11.1) is that the same outputs are recorded, but the value of the disservice is made explicit. This accounting treatment can be also applied where there is no off-setting ecosystem service, for instance GHG emissions could be recorded as a negative output of an ecosystem and used by households thus reducing their final consumption.

Table 12.2: Complementary table with an ecosystem disservice in the supply and use table

	Ecosystem assets	ISIC A: Agriculture	ISIC C: Manufacturing	Household	Total
Supply					
Ecosystem Service A	70				70
Ecosystem Disservice B	-20				-20
Product X: Crops		200			200
Product Y: Canned goods			80		80
Use					
Ecosystem Service A		70			70
Ecosystem Disservice	0	-20			-20
Product X: Crops			25	175	200
Product Y: Canned goods				80	80
Value Added (supply less use)	50	150	55		255
Transfer	-50	50			0

Disposable Income	0	200	55	255	255

12.26 Table 12.3 adjusts the example of the ecosystem disservice to show a recording for negative externalities. Suppose the farmer disposes agricultural wastes into a river, causing costs to downstream users (in this example ISIC E, a water supply company). The externality can be recorded as a negative output of the farmer (ISIC A) (-20) thereby suppressing its output (and value added). In the use table, the externality can be recorded as (negative) intermediate consumption (-20) by the ecosystem, reflecting that in this situation, the ecosystem is the subject of the externality. This has the effect of showing the value added of the ecosystem in the absence of the externality (i.e., 75), while still portraying the actual ecosystem services supplied (55) and used (25 by ISIC A and 30 by ISIC E). The income transfer (75) ensures, as in the previous recording of disservices, that the ecosystem has no disposable income, and that the activities have the same value added as without the ecosystem service and the externality.

Table 12.3: Complementary table with an externality in the supply and use table

	Ecosystem assets	ISIC A: Agriculture	ISIC E: Water supply	Household	Total
Supply					
Ecosystem Service A	55				75
Externality		-20			-20
Product X: Crops		200			200
Product Z: Water			300		300
Use					
Ecosystem Service A		25	30		70
Externality	-20				-20
Product X: Crops				200	200
Product Z: Water				300	300
Value Added (Supply less Use)	75	155	270		500
Transfer	-75	45	30		0
Disposable Income	0	200	300		500

12.27 In many situations, the discussion of negative externalities and ecosystem disservices relates to the effects on human and population health. It has long been established that the national accounts do not place a direct value on health outcomes and instead the focus is placed on measuring the inputs to human health, e.g., outputs related to doctors and hospitals. Similarly, in ecosystem accounting, there is measurement of the contribution of ecosystems to health outcomes (e.g., via air filtration services) but not measurement of the health outcomes themselves.

12.28 Thus, an important area of analysis beyond the ecosystem accounts lies in direct measurement of these outcomes. This has been undertaken, for example, by the World Bank and the OECD among others under the generic heading of measuring the costs of environmental degradation (COED).[130] Such work will involve some form of monetary valuation but may also involve the measurement of dose-response functions that track the changes in population health in relation to changes in, for example, ecosystem condition (e.g., involving measures of water quality). It should be apparent that the structure of ecosystem extent and condition accounts, together with the biophysical modelling required for

[130] See for example the World Bank Changing Wealth of Nations reports, the OCED database on these costs and Muller et al. (2011).

measuring many ecosystem services, may be applied usefully in the derivation of health-related metrics and the related analysis.

12.29 There are also a range of approaches within the private sector wherein the monetary value of externalities is added or subtracted from an existing measure of financial income or profit. These approaches are commonly labelled as environmental profit and loss (EP&L) statements. In general, these seek to assess the overall (or net) cost or benefit that a company contributes to society, for example by deducting the social cost of carbon associated with its emissions from its measure of financial profit.

12.3 Alternative measures of income, wealth and degradation

12.3.1 Introduction

12.30 Chapter 11 described the SEEA EA approach to the measurement of income and wealth that are adjusted for ecosystem degradation. In summary, the approach involves measuring the value of degradation in terms of the loss in the future value of ecosystem services due to a decline in ecosystem condition and deducting this cost of capital from the relevant aggregate measure of income (e.g., GDP) or wealth. At an industry or institutional sector level, the cost of ecosystem degradation is attributed to the economic units who suffer the loss of future ecosystem services.

12.31 Other approaches to accounting for the effects of degradation on income and wealth have been developed. They vary in terms of the ways in which they estimate the cost of ecosystem degradation and in terms of the definition of income and wealth. Thus, while the general ambition of these measures is similar, there are conceptual and practical differences compared to the estimates derived using the SEEA EA approach. In most cases, the data contained in the ecosystem accounts or data from the SEEA Central Framework can be used to support the derivation of alternative measures but usually additional assumptions and alternative valuation concepts will be applied.

12.3.2 Restoration cost-based approaches to measuring degradation

12.32 Earlier iterations of the SEEA focused not on valuing ecosystem (or environmental) assets per se (in terms of the future value of ecosystem services) but on measuring the cost of degradation directly. This was done in terms of the environmental cost associated with recorded levels of economic activity. The SEEA 1993 recommended to use the so-called restoration cost (or maintenance cost) approach to value degradation, i.e., the costs required to restore the environment to a previous or agreed condition. Further, as explained more fully in SEEA 2003, chapter 9, the conceptual focus assumed that environmental assets – air, water, soil – were effectively fixed in quantity and focus should therefore be placed on either the costs involved in combating declines in the quality of these assets (restoration costs) or the damages incurred as a result of declines in quality.

12.33 In terms of monetary valuation, there are a number of considerations that emerge from this framing. First, in a situation where the environmental quality meets or exceeds a suitable threshold – e.g., there is sufficient clean air – then it is posited that there is no additional cost that needs to be considered in accounting for degradation.

12.34 Second, the non-market benefits that people obtain from nature are not considered as exchanges with economic actors. Hence there is no rationale for extending the production boundary to record ecosystem services as described in the SEEA EA framework. Indeed, the distinct focus of the restoration-cost approach is not on articulating the contribution that ecosystems make to well-being but on highlighting the direct costs of reducing ecosystem condition below acceptable thresholds.

12.35 Third, it was considered that there was no market or institutional mechanism by which the restoration costs are confronted with the benefits (reductions in damages) associated with the change in environmental quality. The consequence of this was that the SEEA 2003 described both cost-based methods and damage-based methods for estimating the monetary value of degradation. The damage-based methods described in SEEA 2003 have much in common with the measurement of welfare values as applied in the measurement of negative externalities and these are not further discussed here. In an environmental accounting context, most focus has been retained on cost-based approaches.

12.36 Following SEEA 2003, cost in relation to environmental degradation can either be preventative – avoidance and abatement costs – or aim to reverse the effects – restoration costs. In the context of accounting for the cost of degradation in any given period, as described in SEEA 2003, chapter 10, the avoidance and abatement costs may have been incurred in which case the quantity of degradation will be reduced, *ceteris paribus*, and further they will already be recorded in the accounts. (The SEEA Central Framework, chapter 4 describes the framework for identifying and recording these costs in environmental protection expenditure accounts.)

12.37 Thus, placing a value on the actual change in environmental quality must focus on restoration costs, the expenditure required to return the environment to a given condition. This condition could be the condition at a previous (or sustainable state), or the condition defined as a societally desired state (e.g., as expressed in multilateral environmental agreements). This focus thus captures any degradation not included in measures of actual avoidance and abatement costs.

12.38 Measuring restoration costs may be challenging for two reasons. First, they are estimates of future expenditure which will require the use of appropriate assumptions concerning prices and quantities of inputs required. The core assumptions are that the costs will reflect the least cost estimate and that there is broad agreement that the expenditures are justified. In some cases, quite extensive information on future restoration costs may be available, for example mining companies may be required to estimate the cost of rehabilitating mine sites. However, it must also be recognised that restoration may take a considerable period of time. Measurement in this area is related to an emerging issue in the context of the SNA concerning the recording of provisions wherein liabilities may be recognised in relation to potential future costs. While provisions are a common feature of corporate accounting, they are not recorded in the national accounts.[131] To the extent that some of these costs are actually incurred, an accounting-based dataset may be maintained to support the estimation of these costs for future periods.

12.39 Second, it is necessary to assume an appropriate environmental quality to which the condition should be restored. Ideally, determining this level of quality should involve (i) an understanding of the benefits obtained from the ecosystem (e.g., ecosystem services, intrinsic values); (ii) an understanding of relevant ecological thresholds and boundaries; (iii) identification of the socially desired state; and (iv) connections to relevant environmental regulations, standards and policy which can be used as indicators of social preferences. The determination should also recognise that in many cases ecosystems cannot be fully restored to a natural state. Based on the assumptions concerning the socially desired state, the estimated costs would reflect a social willingness to pay for a level of environmental quality.

[131] Although the recognition of these costs is an active area of research in an SNA context.

12.40 A simplifying assumption might be applied wherein the degradation is the estimated cost associated with restoring the ecosystem to its condition at the beginning of the accounting period. In all cases, there is a clear role for the ecosystem condition account in supporting the assessment of degradation and the associated restoration costs. Note that if these costs were actually paid during an accounting period then, in theory, condition should be unchanged and no degradation should be recorded. Therefore, taking such a cost-based approach may be better understood as an example of applying the accounts for scenario analysis.

12.41 In general, the estimate of the monetary value of degradation obtained using this approach could be integrated into the accounts as a macro adjustment. Recognizing the nature of these costs, Vanoli (2015) proposed to add the monetary value of degradation of ecosystems to the final expenditure categories as "unpaid ecological costs". This would then record final consumption and gross fixed capital formation on a "total costs" basis. Further, where the costs accrued remain unpaid in subsequent periods, they would be recorded as a negative with respect to saving, and consequently recorded as an increase in a new liability category, "ecological debt of the economy". Table 12.4 below shows how unpaid ecological costs and ecological debt may be incorporated into a sequence of accounts.

12.42 As noted, this approach can provide a means to estimate a cost of degradation but it cannot be easily combined with direct measures of the value of ecosystem services and associated values of ecosystem assets as described in the ecosystem accounts since there is no particular reason that the estimated restoration costs will align with the estimated loss of future flows of ecosystem services. Nor is there a reason that the estimated costs will reflect the social willingness to pay for the future ecosystem services. One option may be to apply this approach in cases where no underlying ecosystem asset is recognized, such as in the case of the atmosphere or fisheries on the high seas. Restoration costs for these environmental assets could be recorded as unpaid ecological costs alongside measures of degradation for ecosystem assets as described in the core ecosystem accounts.

12.3.3 Polluter pays presentation of degradation

12.43 The recording in the SEEA EA is based on the cost borne perspective in which the cost of degradation is allocated to the economic unit considered to own the ecosystem asset since they are the unit that suffers from the loss. An alternative perspective is to allocate the costs of degradation to the economic unit that is considered to have caused the degradation, for example costs may be assigned to a polluter (La Notte & Marques, 2019).

12.44 To support this alternative presentation, Table 12.4 illustrates how it is possible to include both cost caused and cost borne presentations in the sequence of accounts, compared with the sequence of accounts displayed in Table 11.3. It is done by allocating degradation on the basis of cost caused in the production account, and then transferring degradation costs between sectors in the distribution of income account by including two additional rows - a degradation transfer in kind payable and receivable. The transfer ensures that the same degradation adjusted disposable income is obtained as in Table 11.3. In Table 12.4, it is assumed that the farmer is responsible for all degradation.

12.45 This presentation has the advantages that (i) the ecosystem asset value underpinning the supply of services reflects the costs borne perspective (i.e., reflecting the value of the asset to the economic owner); and (ii) the measures of production and value added show a measure of net value added reflecting a costs caused perspective.

12.46 These allocations to causing units may be difficult to assign in practice, for example in cases where the effects of degradation arise some distance from the cause; where there are multiple economic units contributing to the degradation; or when there is a significant time lag between the activities causing the degradation and the incurrence of costs by other economic units.

Table 12.4: Alternative recording of degradation costs in the sequence of accounts (excluding financial account)

			Extended sequence of accounts			
			Sector			
			Agri.	Household	Ecosystem trustee	Total
Production and generation of income acccount						
	Output	Products (wheat)	200			200
		Ecosystem services (crop provisioning)	80			80
		Ecosystem services (air filtration)			30	30
	Total output		280		30	310
	Intermediate consumption	Products	0		0	0
		Ecosystem services (crop provisioning)	80		0	80
	Gross value added		200		30	230
	less Consumption of fixed capital (produced assets)		10		0	10
	less Ecosystem degradation (polluter pays)		15		0	15
	Degradation adjusted net value added		175		30	205
	less Compensation of employees		50		0	50
	Degradation adjusted net operating surplus		125		30	155
Allocation / Use of income accounts						
	Degradation adjusted net operating surplus		125		30	155
	plus Compensation of employees			50		50
	Ecosystem service transfer in kind payable				30	30
	Ecosystem services transfer in kind receivable			30		30
	Degradation transfer in kind payable				5	5
	Degradation transfer in kind receivable		5			5
	Degradation adjusted disposable income		130	80	-5	205
	less Final consumption	Products (wheat)		200		200
		Ecosystem services (air filtration)		30		30
		Unpaid ecological costs		25		25
	Degradation adjusted net saving		130	-175	-5	-50
Capital account						
	Degradation adjusted net saving		130	-175	-5	-50
	plus Consumption of fixed capital (produced assets)		10			10
	plus Ecosystem degradation		10		5	15
	Net lending/borrowing		150	-175	0	-25
Changes in balance sheet						
	Changes in fixed capital (SNA)		10			10
	Changes in ecosystem assets (non-SNA)		10		5	15
	Changes in ecological debt (non-SNA)			25		25

Note: In yellow: cells changed / added in a polluter pays recording in which ecosystem degradation of 15 currency units is allocated to the polluter. In orange: cells added/changed when including unpaid ecological costs where these costs are assumed to relate to environmental assets outside the scope of these sector's balance sheets e.g. the atmosphere or fisheries on the high seas. The unpaid ecological costs are therefore additional to the recorded ecosystem degradation.

12.3.4 *Defensive expenditures*

12.47 Another long-standing framing in the economics literature is adjusting aggregate measures of income for expenditures incurred to avoid bad or negative outcomes. This includes, for example, the purchase of equipment to filter polluted air. These so-called defensive expenditures add to measures of national income following the SNA (i.e., there is increased production and consumption of relevant goods and services) but may be considered not to enhance overall welfare. Thus, defensive expenditures may be deducted to provide a more appropriate measure of national income in terms of welfare. A challenge in this approach is defining the measurement boundary for defensive expenditures.

12.3.5 *Alternative measures of environmental income*

12.48 The ecosystem accounts involve treating the monetary value of flows of ecosystem services as output, and hence income. Consequently, expectations of future income flows will affect the monetary value, and changes in value, of ecosystem assets. As described in chapter 10, there is a range of entries to record the change in value of ecosystem assets including changes in value due to ecosystem enhancement, ecosystem degradation, ecosystem conversions and other changes. These other changes in asset values are accounted for following national accounting treatments as either other changes in volume (e.g., resulting from catastrophic losses) or revaluations. Importantly, these entries are not considered part of income in a national accounting context.

12.49 An alternative framing[132] is to define income such that it includes all changes in asset values – including other changes in volume and revaluations. Such an approach has many similarities to the ecosystem accounting approach described in the SEEA EA. The primary difference concerns the use of a Hicksian measure of income that explicitly incorporate all changes in asset values in a manner that is not aligned with the SNA. All of the underlying accounting entries and valuations are however aligned, including the use of the exchange value concept.

12.3.6 *Alternative approaches to asset valuation*

12.50 The recording of the monetary value of ecosystem services and the consequential extension of the monetary value of environmental assets relative to the SNA is consistent with the central logic of wealth accounting as described in, for example, Barbier (2013). At the same time, there are a range of alternative assumptions that can be applied in implementing the central logic of wealth accounting compared to the treatments and boundaries described in the ecosystem accounts. Of particular note are the following:

- For some biological resources, especially fish stocks, where there is limited regulation and open access fishing is possible, the resource rent which reflects the price of the asset will fall to very low levels. In these contexts, it may be of interest to estimate the value of the fish stocks and the associated ecosystem asset using an alternative institutional context to evaluate the effects of making such a change. These values might be considered unrealized values.
- Also for biological resources, but indeed for all ecosystem services, it may be of interest to estimate the present value of future returns using alternative institutional

[132] See Caparrós et al. (2003).

arrangements, for example, assuming some optimal management of the resources. These values might also be considered unrealized values. A specific case would be estimating values of assets under an assumption of long-term sustainable use of the ecosystem which might be considered “sustainability-based values”.

- Alternative valuation concepts may be applied wherein estimates of consumer surplus are included in the value of future flows of ecosystem services.
- When valuing individual ecosystem assets, there may be interest in deducting the value of ecosystem disservices to the extent that these are understood to have a negative overall effect on the value of the asset in terms of its contribution to society.
- When defining future income flows, alternative treatments and interpretations of capital gains and depreciation may be applied compared to standard national accounting principles.

12.51 In the context of these various assumptions and treatments for wealth accounting, the values obtained from the ecosystem accounts can be considered one alternative. In all contexts, it will be relevant to clearly describe the selected assumptions and treatments such that the differences between various wealth accounting estimates can be clearly understood. This documentation should also extend to a clear articulation of the set of ecosystem services used to measure natural capital in the wealth accounts, as well as information on, for example, the selected discount rate and asset lives.

12.3.7 Extended modelling/greened economy modelling

12.52 A general concern for all measures and aggregates in monetary terms when using an extended income framing is that the values of the environmental variables reflect the current imperfect institutions and regulations for managing the environment-economic system. In this context, one alternative approach is to undertake extended modelling to estimate an alternative GDP (and other income measures) under the assumption that alternative environmental constraints (e.g., restrictions on pollution) are in existence. 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 (SEEA 2003, section 11.F.4).

12.53 More generally, there are a range of possible applications of the accounts in scenario analysis. The *Technical report on policy scenario analysis using SEEA ecosystem accounts* (UNEP & UNSD, n.d., forthcoming) is forthcoming.

12.4 Corporate natural capital assessments

12.54 In parallel with the advances in environmental-economic accounting in the public sector, there have been strong advances in natural capital accounting in the corporate sector in recent years. In general, these approaches have tended to focus on considering the impact of corporate activities on the environment, with a particular focus on GHG emissions and other pollutants, but there is an increasing shift towards understanding dependencies on water and increasingly on ecosystems and biodiversity.[133]

12.55 Most commonly this has been taken forward using an externalities framing as described in the section above, particularly in the compilation of environmental profit and loss accounts.

[133] See https://seea.un.org/sites/seea.un.org/files/background_paper_release_for_unseeaforum.pdf

As well, the approaches have been used in a range of applications including undertaking risk analysis, identifying operational efficiencies and securing access to sustainable finance.

12.56 There are also a number of approaches being used at corporate level that share the spatially-based approach of the ecosystem accounting framework (e.g., Corporate Natural Capital Accounting, Biodiversity Protocol, the UK Natural Capital Accounting for Organizations).[134] However, there are also differences between these approaches and the SEEA-based accounts. In particular, these differences arise from the type of analytical question posed, which in the corporate approach is often driven by reporting requirements focusing on business impacts on society, and which therefore tend to apply welfare rather than exchange value based approaches to valuation. In addition, there are also questions on the extent to which the data underpinning the compilation of SEEA-based accounts is sufficiently detailed for corporate scale measurement and analysis.

12.57 Given the potential for collating consistent and spatially detailed physical and monetary data using the ecosystem accounting approach, there is likely considerable potential for cross-fertilisation of efforts in collating environmental data that support shared measurement of ecosystem extent, condition and ecosystem service flows. Shared measurement should encompass the sharing of data, the use of agreed classifications and the application of coherent definitions. It is likely that issues of monetary valuation will continue to be an area of discussion but this is equally true in the context of public sector accounting and analysis. Further engagement on the development of accounting principles and their harmonization at national and corporate levels, as well as on the potential for the development of rich datasets to underpin accounting at all scales is an important area of development.

[134] See eftec (2015) and the British Standards Institute at https://www.bsigroup.com/en-GB/our-services/events/webinars/2020/bs-8632/.

Annex 12.1: Exchange and welfare values in an accounting context

A12.1 This annex provides a technical summary of the relationship between exchange value-based accounting and monetary values focused on the measurement of welfare.

Monetary valuation of individual goods and services

A12.2 To establish the concepts, initial focus is on the valuation of a single marketed good and a single consumer and producer. The basis of monetary valuation in neo-classical economics assumes that people and businesses have preferences that can be represented in quantitative terms using money values as a common unit or numeraire. The preferences are based on the willingness of individuals to pay (WTP) for a given good or service or on individuals, firms, or resource owners' willingness to accept a payment (WTA) for giving up a good or service.

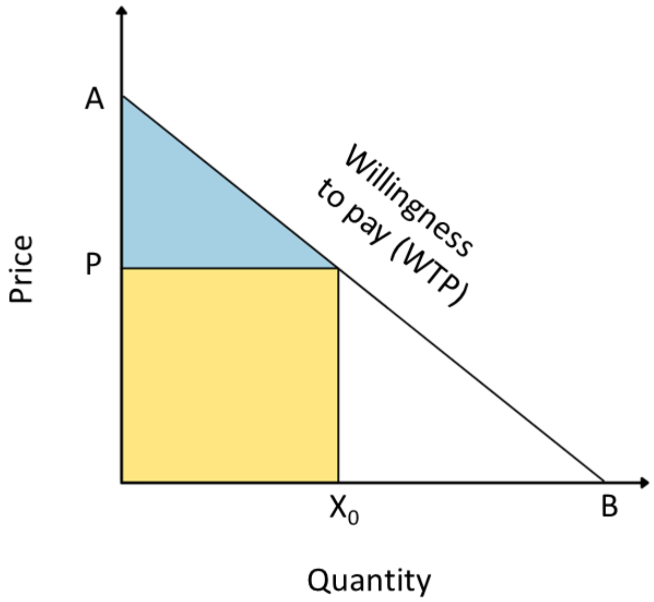
A12.3 The WTP and WTA for a good or service can be represented as a demand curve for the good or service under consideration. In Figure 12.1 the horizontal axis represents the quantity of the good and the vertical axis the price. For most goods, an individual's WTP decreases with each additional unit that they obtain. Or conversely, the quantity they demand decreases as the price increases. The line AB is referred to as the individual´s demand curve because it illustrates the quantity demanded relative to price. The total WTP for quantity Q_0 is the area under the demand curve. If the good or service were sold in a market at a price P, the individual would purchase quantity Q_0 as they are willing to pay more than P for all the units before Q_0 but their WTP for an additional unit (Q_0+1) is less than P, so they will not purchase another unit at that price.

A12.4 In this case, the sum of money exchanged is the yellow area and is referred to as the ***accounting value*** reflecting the value that is recorded in the accounts. The blue area is a benefit that individuals who obtain the good or service enjoy over and above what is paid and is called the ***consumer surplus.***[135] If the good is provided for free and there are no costs associated with supplying the service, then the consumer surplus is equal to the whole area under the demand curve (i.e., the triangle A, B, 0).[136] For further details on consumer surplus, WTP and WTA see Markandya et al. (2002).

[135] Economic theory distinguishes between the Hicksian and Marshallian approaches to estimating demand curves the former aligning demand and preference to the concept of utility and the latter to the concept of income. Ideally, Hicksian demand curves based on utility would be measured but in practice income is the more measurable concept. Consumer surplus is thus an approximation to the ideal.

[136] For essential goods like water, the consumer surplus can be very high (arguably infinite) as a person´s WTP for the amount needed for survival will be very large. This has been also called the zero problem (Nordhaus, 2006). It would also mean that the consumer surplus is also infinite. This is one of the reasons welfare analysis usually focuses on assessing changes in welfare (e.g., between q1 and q2, rather than between q1 and 0).

Figure 12.1: WTP, Exchange Values and Consumer Surplus

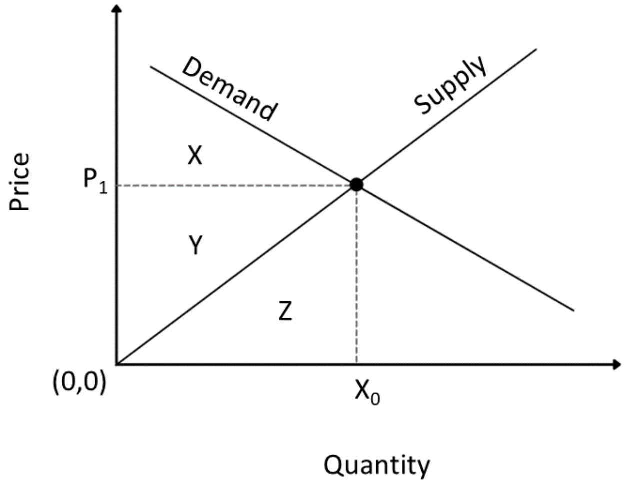


A12.5 To complete the picture of a market for a single good, a supply curve (Figure 12.2) can be incorporated which reflects the preferences of the producer in providing a good for sale; again in terms of a combination of prices and quantities. Since the producer will be willing to supply more of a good as prices rise, the supply curve will be upward sloping. The nature of the supply curve will be affected by the costs of supply, i.e., a producer will only be willing to accept a price for their goods that covers the costs.

A12.6 The transactions in ordinary goods and services are based on prices whereby the price is determined by the point at which the marginal WTP is equal to the marginal cost of producing a good or service. This is the point of intersection of the supply and demand curve, denoted as point A in Figure 12.2. Point A which provides both an exchange price and the quantity of the good exchanged. Data concerning these transactions form the foundation of all SNA accounts.

A12.7 Area Z reflects the costs of supply. The ***producer surplus*** (area Y) is the additional benefit that a producer receives from selling quantity Q_0 at price P given costs of Z.

Figure 12.2: Static one-good market



A12.8 The welfare value or total surplus, as understood in welfare economics, is equal to the area X + Y, i.e., the sum of the consumer surplus and producer surplus. It represents the total benefit accruing to consumers and producers in this one good market from exchanging the quantity of the good at price P. If preferences change, costs change or incomes change, then the measured total surplus will change. Commonly, welfare analysis involves assessment of the change in total surplus that would arise in a different context, for example as the result of a policy change (e.g., tax rates).

A12.9 The relationships between the areas X, Y and Z will depend on the slopes of the supply and demand curves. For example, if the demand curve is horizontal then consumer surplus (X) will be zero and the total surplus will equal the producer surplus. If the supply curve is vertical then costs (Z) will be zero and the accounting value will equal producer surplus (Y). While there are a range of different combinations that can be envisaged in terms of the relationship between accounting values and total surplus, the nature of these combinations is not critical to the discussion here.

A12.10 There are two key implications to consider from Figure 12.2. The first concerns the link between price and accounting value. In short, the price of a good is what is paid for it which needs to be multiplied by the quantity to establish the accounting value. If there is no rationing involved, people will continue buying goods until their WTP equals the price at which the goods are offered. The price can therefore also be referred to as the marginal value of the good. A similar logic can be applied from the perspective of the producer of the good, i.e., the price will reflect the marginal cost of the good to them.

A12.11 Second, from the discussion in this section, the welfare derived from a good or service is equal to the total WTP for it, which includes the payment made and the consumer surplus. As is well understood in the national accounts' literature, accounts do not include the consumer surplus and instead record accounting values. A link with welfare can nonetheless be posited because the price is also the marginal value of a unit, which is the welfare that unit provides. Thus, a small increase in the availability of a good will generate a change in welfare approximately equal to the change in the accounting value. This insight is the basis of a formal proof in the literature that variations in material wellbeing in society are reasonably well represented by the changes in net domestic product (NDP) (see Weitzman (1976)). Thus, the change in GDP less any change in depreciation, which gives the change in NDP, is an approximation for the change in wellbeing generated in society.

A12.12 This result does require a restrictive set of assumptions. These assumptions have been partially relaxed in subsequent studies (see Harberger (1971)) for a previous and similar result and Löfgren (2010) for a survey of this literature and a discussion about the assumptions needed) but the link between changes in GDP/NDP and changes in societal welfare needs careful reflection. Of particular note, is that the result obtained assumes the absence of externalities and that all goods and services are provided through competitive markets. As well, there are connections to wealth distribution and relative poverty which will be important in determining individual wellbeing that are not captured in aggregate measures. More broadly, making the connection between accounting values and well-being should recognise that accounting values will reflect an instrumental perspective of value and other value perspectives should also be considered, as introduced in section 2.4.

A12.13 From an ecosystem accounting perspective, an important assumption in the Weitzman result is that the products included in the income measure (i.e., GDP) all correlate positively with wellbeing. In turn, this places a focus on the scope of goods and services applied (i.e., the choice of production boundary) and whether this scope includes some things that have a negative link to wellbeing or whether there are goods and services that contribute positively to wellbeing that have been excluded. Indeed, one of the motivations for the development of ecosystem accounting is the potential to consider (i) some of the good and services excluded from GDP; and (ii), and the effects of losing the access to them as a result of ecosystem degradation.

Extension to non-market values

A12.14 The focus in this annex has been supply and demand curves of a single consumer and producer. The demand curves for all individuals in a given market can be added together to construct a total or market demand curve. The summation is done horizontally if the good is a private good. Thus, for any given WTP, the quantity that each individual demands for that WTP is summed to get the total WTP for the good. For (quasi-)public goods, such as recreation-related services, the aggregate demand is not the horizontal summation as for private goods, but the vertical summation. That is, for any given quantity of the good, the WTP of each individual is summed to get a total WTP. This happens when the supply is (relatively) inelastic (e.g., in the case of a protected area supplying cultural services, it may take time to increase the supply of lodging, parking or access roads in response to an increase in demand).

A12.15 The average cost of producing a good or service does not directly relate to its value to the consumer (noting for example the exclusion of consumer surplus), although the more expensive it is to produce, the higher its price is likely to be, making the marginal value higher. In the SNA, a number of goods are valued at their cost of production because there is no market for them and hence no observed price. This is the case with public goods provided by the government and other authorities, such as defence or public health. The use of cost data in this context, however, does not mean that levels of provision are unrelated to values; the link can come about through the political process that determines the level of provision. Thus, a given level of spending on health, education, transport etc. reflects societies´ collective willingness to pay for these services through taxes and user charges. That said, the relationship between public expenditure data and the true value of the goods and services is subject to ongoing discussion.

A12.16 A key characteristic of ecosystem services is that there is often no accompanying exchange of money that can be used to quantify the preferences for the services in the same manner as for the marketed goods just described. As a result, as discussed in chapter 9, to support the valuation of ecosystem services, and many other non-market goods and services, a wide range of valuation techniques have been developed for use in pricing ecosystem services where market prices are not available.

A12.17 While these techniques may be commonly applied to estimate changes in welfare values, they all involve the estimation of the marginal WTP for a good or service. Consequently, using the framing described above, these techniques can also be applied to estimate prices for accounting purposes. That is, a marginal WTP multiplied by a revealed quantity exchanged will estimate an accounting value.

A12.18 An important issue in understanding the potential to use marginal prices concerns assumptions about the institutional arrangements or market structure. Generally, it is expected that prices will be estimated assuming that the current institutional arrangements relate to the transaction in ecosystem services. Hence, prices used to estimate accounting values need not align with estimates of marginal WTP made using theoretically preferred institutional arrangements or market structures, such as perfect competition.

A12.19 Where there is a close connection to a marketed good or service, the potential to infer preferences and hence a marginal WTP will be relatively high. Further, in these cases, it will likely be reasonable to assume that the institutional arrangements pertaining to the observed price of the related good or service can be applied in estimating the marginal WTP (provided that the context (ecosystem, location, etc) is sufficiently similar). However, there will be other cases where there is no close connection to a marketed good or service, in which case establishing preferences and determining the appropriate institutional arrangements will be difficult. Different techniques have developed to consider these different contexts as discussed in chapter 9.

13 Accounting for specific environmental themes

13.1 Introduction

13.1 The framing provided by ecosystem accounting is systematic and comprehensive with respect to ecosystem extent, ecosystem condition and ecosystem services and provides one perspective on monetary values of ecosystem services and ecosystem assets. Collectively, this data set allows for broad scale measurement of trends in ecosystems and their services and supports the incorporation of ecosystem related data into standard economic reporting and analysis. These aspects emerge from the set of five ecosystem accounts, and the extended accounts and complementary valuations described in chapters 3 to 12. However, policy and analysis about the environment and human connection to it can be framed in many ways. Often it requires considering specific environmental themes, such as biodiversity, climate change, oceans and urban areas, among many others.

13.2 This chapter introduces ways in which data from the ecosystem accounts, together with data from other accounts of the SEEA Central Framework and the SNA, and data from other sources, can be used to support discussion and analysis from a thematic perspective, i.e., when considering specific themes. This use of accounts is collectively referred to as thematic accounting. The benefit of thematic accounting is ensuring consistency with additional data sets that can then be used to underpin reporting and decision making for a given theme. Securing this benefit may require additional spatial disaggregation of data (e.g., of economic data) and the use of consistent classifications, but these are common challenges in implementation of ecosystem accounting and SEEA generally.

13.3 Section 13.2 describes the general principles involved in combining accounts, including the accounts from the SEEA Central Framework. Data from these accounts, including for example accounts for water and land,[137] complement and support compilation of ecosystem accounts and thematic accounting. Sections 13.3 to 13.6 present four examples of thematic accounting: biodiversity, climate change, oceans and urban areas. Each of these themes have been of wide-spread policy interest. Using the same general principles, thematic accounting may also be considered for other themes such as protected areas, wetlands, mangroves and forests.

13.2 General principles of thematic accounting

13.4 All SEEA accounts build from the accounting principles described in the SNA. Much focus is placed on the consistent approach to valuation concepts across these accounting frameworks. However, of more importance in the organisation and integration of data, is the consistent application of rules and treatments concerning measurement boundaries and the use of consistent classifications. These rules and treatments allow accounts to be adapted to suit specific purposes and hence place relevant data in context. They further support the development of broad and coherent links with additional information systems for each theme. This section describes the three types of rules and treatments that are of most relevance in thematic accounting.

13.5 First, it is necessary to have a clearly agreed geographical area. In ecosystem accounting, this is referred to as the EAA. At a national level, this will align closely with the SNA concept of economic territory. For thematic accounting, a focus on a more targeted area may be

[137] This work will also be complemented by guidance from documents such as the SEEA Water (United Nations, 2012), the SEEA AFF (FAO & UNSD, 2020) and the Forest Accounting Sourcebook (Castaneda Sanchez et al., 2017).

appropriate – for example, the focus on coastal and marine ecosystems in ocean accounting. Delineating this area allows for the relevant set of ecosystem assets, economic units and other accounting entities to be appropriately delineated and allows the measurement focus of the accounts to be clearly defined and aligned across different accounts.

13.6 Second, it is necessary to have a set of entities that are the focus of accounting. In ecosystem accounting, the focus is on ecosystems, in the SNA the focus is on economic units and in the SEEA Central Framework the focus is on individual stocks and flows. In thematic accounting, a number of different types of entities are integrated. Once the entities are selected, it is then appropriate to choose relevant classifications. In ecosystem accounting, the relevant classifications concern ecosystem type and ecosystem services. In the SNA, the relevant classifications concern the classification of economic units by economic activity (ISIC) and institutional sector, and also the classification of products. In the SEEA Central Framework, the classifications relate to details of specific individual stocks and flows, for example classifications of land, soil, minerals and energy resources, and air pollutants. The selection of entities and their classification enables accounts to be structured to organise and present the relevant information for the theme.

13.7 Third, in accounting for a single theme, multiple accounts will be required. It is evident from the SEEA and SNA frameworks that multiple accounts are required to organise the relevant information – i.e., there is no single ecosystem account or economic account. The same applies in thematic accounting. The number of accounts developed to support discussion of a given theme will vary depending on the analytical questions and the data availability. While a number of accounts will be required, each account has relevance and merit in its own right by reflecting relevant accounting principles. For example, asset accounts will provide an opening and closing position and a full description of changes in the relevant stock, and supply and use tables will balance the supply and use between entities.

13.8 Links between the various accounts for a theme are possible because of the use of a clearly delineated and consistently applied geographical boundary and consistent application of classifications for agreed entities. This allows the accounts for one theme to convey a coherent narrative. These features also allow for the derivation of consistent indicators and support the integration of data into models and other analytical tools.

13.9 For any given thematic accounting exercise, there is no *a priori* restriction on the geographical area, type of entity or classification that must be applied. However, it is likely to be advantageous to link the selection of geographical areas, definition of entities and choice of classifications to existing data and decision-making processes. Thus, for example, a geographic scope that aligns with administrative boundaries may be most useful. This will allow existing data to be more readily incorporated and more importantly, will facilitate the use of data from the accounts in decision making. Further, where common classifications can be used for data from different sources (e.g., concerning classification of ecosystem types, economic units) it will support (i) comparison of information across themes; and (ii) improved and streamlined data collection and reuse.

13.10 Accounting principles themselves are equally applicable across different spatial scales and entities and are unaffected by the choice of classification. These choices should therefore be made with a focus on the use of the accounts, including the potential to compare results over time and in different locations.

13.11 In practice, thematic accounting is most likely to be applied in one of the following ways:

- By extending or adapting an existing account from the SEEA to provide additional detail or to use alternative classifications. For example, for the theme of forests it may be appropriate to compile adapted extent and condition accounts at the level of forest species and by making distinctions between different types of land use and management arrangements.

- By focusing on a specific entity or group of entities and building associated accounts. For example, in accounting for the theme of climate change, the likely core focus is on accounts for stocks and flows of carbon, and in accounting for the theme of biodiversity, it will likely be relevant to compile accounts for a target group of species or taxa.
- By focusing on a type of area that has specific management and policy relevance. Examples include protected areas, urban areas and coastal and marine areas. Often there will be a link to specific ecosystem types but the framing of thematic accounting looks beyond the ecosystem accounts to consider the relevance of other SEEA and SNA accounts in supporting the design of a more comprehensive data set.

13.12 Under each of these approaches, which themselves may be combined, there remains a need to specify the relevant geographical area for the set of thematic accounts. Thus, thematic accounts can be compiled at a national level, for large administrative regions within a country, or at relatively detailed landscape and catchment scales. Further, for some themes, the compilation of global scale accounts may be of relevance, for example for climate change or for the assessment of environmental and economic outcomes on the high seas, beyond national jurisdiction. Whatever geographical area and scale is chosen, accounting designs based on the principles of the SEEA can be developed.

13.13 While the development of thematic accounting has emerged through the development of ecosystem accounts, there are many relevant accounts in the SEEA Central Framework that should be used in combination with ecosystem accounts to support accounting for any given theme. The relevant SEEA Central Framework accounts for the four themes selected for description in this chapter are described in the following sections. A more general introduction to the relevant SEEA Central Framework accounts is provided in annex 13.1. It is further noted that, in some cases, the data from SEEA Central Framework accounts will provide input to the compilation of ecosystem accounts. For example, data from the water resources asset account and the carbon stock account can support the measurement of ecosystem service flows and the derivation of ecosystem condition indicators.

13.3 Accounting for biodiversity

13.3.1 Introduction

13.14 The definition of biodiversity comprises three levels – ecosystems, species and genes – as reflected in the CBD definition of biodiversity being *"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 a part; this includes diversity within species, between species and of ecosystems."*[138]

13.15 The ecosystem accounts describe how accounting principles can be used to organise a wide range of data concerning ecosystems in a manner that supports understanding the connection between ecosystems and economic activity and human well-being. This subsection describes the potential to use ecosystem accounts and other accounting data to support decision making on biodiversity more broadly, with a particular aim of mainstreaming the use of data on biodiversity in planning and decision making. Collectively, this use of accounting is referred to as accounting for biodiversity. The ambition to support the

[138] See CBD, article 2, entitled "Use of terms" https://www.cbd.int/convention/articles/?a=cbd-02.

mainstreaming of biodiversity into national policy and related decision making is reflected in the IUCN Resolution WCC 2020 Res 057 "Accounting for biodiversity: Encompassing ecosystems, species and genetic diversity."[139]

13.16 The purpose in accounting for biodiversity includes informing conservation actions and the enhancement of biodiversity as an environmental management objective in its own right, as well as discussion about securing ecosystem services supply, and about various policy responses that may be relevant, such as biodiversity finance. Accounting for biodiversity recognises the CBD definition of biodiversity, the different components of biodiversity, and the links between economic activity and changes in biodiversity.

13.17 This section summarises the connections between biodiversity assessments and the SEEA EA; describes one particular type of accounts, 'species accounts', that complement the suite of ecosystem accounts; notes the relevance of measures concerning the genetic level of biodiversity; and lists the types of accounts that will be relevant in accounting for biodiversity. The discussion here reflects the current state of play on accounting for biodiversity, recognising that a broader and richer discussion of the coverage and application of accounting in relation to biodiversity is required. A future output of these discussions may be a SEEA for Biodiversity.

13.3.2 Biodiversity assessments and the SEEA EA

13.18 There is a wide array of primary data on ecosystems, species and genes that is used to support the measurement and assessment of biodiversity. The focus of biodiversity assessments may be regional, national or global in scale, or may consider individual species or ecosystem types. Work on assessing biodiversity is the focus of a range of global and national measurement initiatives and assessment frameworks including the IUCN Red List of Threatened Species, Red List of Ecosystems, Key Biodiversity Areas; the Intergovernmental Science-policy Platform on Biodiversity and Ecosystem Services (IPBES); the Biodiversity Indicators Partnership; and the Global Biodiversity Information Facility. The GEOBON Essential Biodiversity Variables approach, while not providing assessments or data in itself, provides an organising framework for primary data.

13.19 Given this rich and long standing body of information, accounting for biodiversity is not intended to replace or duplicate existing initiatives in biodiversity assessment, or generate indicators of diversity at ecosystem, species or genetic levels. Further, there is no single "biodiversity account".

13.20 In addition to these assessment frameworks, there are global monitoring initiatives, principally under the CBD and under the 2030 Agenda for Sustainable Development. The current draft CBD Global Biodiversity Framework, for example, has five "pillars". These represent the three levels of biodiversity – of ecosystems, of species and of genetic material – that are embodied in the CBD definition of biodiversity; and two levels of interactions with people and the economy – ecosystem services and biodiversity finance. Data and methods about all of these pillars are relevant in supporting a complete monitoring of, and support for, biodiversity related policy and decision making.

13.21 There are three main connections between the SEEA EA and biodiversity assessment and monitoring frameworks. First, data collected for use in biodiversity assessments can also support the compilation of ecosystem condition accounts and may provide input to the measurement of ecosystem services. For example, data on species abundance and diversity

[139] See https://portals.iucn.org/library/node/49196.

for specific ecosystem types will support measurement of the composition, structure and function of those ecosystems.

13.22 Second, data from various SEEA EA accounts may input to these assessment frameworks and global monitoring initiatives (e.g., CBD) where the focus is on measures pertaining to ecosystems. For example, where data are needed concerning ecosystem extent, ecosystem condition or ecosystem service flows, output data from the ecosystem accounts can provide a relevant source of information.

13.23 Third, data from the ecosystem accounts, particularly concerning ecosystem services, and data from the SEEA Central Framework concerning environmental protection expenditure and environmental taxes and subsidies, can support discussion of the interactions between biodiversity, people and the economy.

13.24 The use of data from the ecosystem accounts for use in the monitoring of biodiversity does not imply that the accounts provide direct measures of ecosystem diversity. Rather, information on ecosystem extent and condition can be used to support an understanding of the status of, and trends in, biodiversity. The potential of ecosystem accounts data to support the derivation of measures of ecosystem diversity is an area for research in advancing accounting for biodiversity.

13.25 Given these various connections, advancing accounting for biodiversity will require developing a coherence with existing national biodiversity objectives and associated international commitments. As such, the ministries responsible for the development of the National Biodiversity Strategy and Action Plans, Multilateral Environmental Agreements and similar policies that deliver on various national and global biodiversity objectives, including the CBD commitments, should be involved in accounting for biodiversity work at an early stage.

13.3.3 Accounting for species

13.26 Environmental-economic accounting has the potential to provide a structured link between the environment and economic activity and human well-being. Consequently, it is relevant to consider the links between selected species and economic activity and human well-being. With this motivation, species accounts can be compiled to support decision making.

13.27 Species accounts measure changes in (i) species "status" in terms of extinction risk over an accounting period; (ii) species stocks (e.g., presence, abundance); and (iii) species distribution.[140] All species accounts have the same general structure with an opening and closing entry and changes over the accounting period. Data within a species account do not generate directly a measure of species diversity but may support the assessment of species diversity and may provide input to indicators of species diversity.

13.28 For each type of account, species are selected as the focus of accounting. Four high level groups for species accounting can be identified: (i) species of concern (e.g., threatened species); (ii) species important for ecosystem services; (iii) species of social or cultural significance; and, (iv) species important for maintaining ecosystem condition (or functioning). A species account may focus on a single species within these groups or a selection of species or taxa relevant to the purpose of the accounting.

13.29 The rationale for accounting for the abundance and/or persistence of the species important for ecosystem services is well established in the context of provisioning services (such as

[140] Species assemblages are a defining characteristic of ecosystems, as such there is also a reciprocal relationship between species and ecosystem extent accounts.

concerning harvest of fish and timber) via the SEEA for Agriculture, Forestry and Fisheries (SEEA AFF) (FAO & UNSD, 2020). For species to be harvested on a sustainable basis, their stocks need to be quantified and assessed in the context of the supply and use of the services. Commercial fishery species are an example here. There are also some regulating services where recording the stocks of particular species groups is important for understanding the sustainability of ecosystem services supply. Populations of pollinator species is an important example.

13.30 Species accounts may also organise data to support measurement of some cultural ecosystem services. For instance, providing data for services involving relations to sacred plants, iconic animals or other species linked to spiritual and symbolic services. Species accounts will also provide useful data to represent elements of biodiversity to which people assign non-use existence or bequest values (recorded via ecosystem and species appreciation).

13.31 The compilation of species accounts will commonly be based on existing data and monitoring programs. Of particular note, is the IUCN Red List of Threatened Species which is underpinned by a comprehensive set of data about species for which Red List assessments have been undertaken. More generally, two approaches to measurement can be described both of which are used in Red List assessments. The 'Direct Observation' approach may be informed by large sample surveys (such as national surveys), stock assessments for commercially valuable species, or more focused efforts (e.g., census of protected areas and nature reserves). Where sampling densities are sufficient and spatially referenced, species accounts can be aligned to ecosystem types and, potentially, ecosystem assets, and integrated with information in the ecosystem accounts.

13.32 Where 'Direct Observation' data on species are limited, as is typically the case, inferred approaches may be used. A particular inferred approach is a habitat-based approach which uses observations of changes in the spatial extent (expressed in terms of area) and configuration of habitat required by individual species or communities of species (UNEP-WCMC, 2016). Inferred approaches underlie a large proportion of Red List assessments. More sophisticated measures can also be applied to estimate species persistence or proportions of species expected to be retained in communities. Data compiled for ecosystem extent and condition accounts represent a potentially valuable source of information for assessing the spatial configuration and condition of remaining habitat for species. In this way, the relationship between changes in ecosystem extent and ecosystem condition, and changes in the suitable habitat available for individual species or species extinction risk can be made explicit.

13.33 The general structure for a species account is shown in Table 13.1. The structure reflects a typical 'asset account' and is similar to the ecosystem extent account. The scale at which the species account is compiled is flexible. However, in practice, it is likely that species accounts will be compiled at the scale of ecosystem accounting areas, either in aggregate or by ecosystem type. The columns in Table 13.1 organize information on selected species (e.g., lions, elephants, etc.) or species groups (i.e., taxa, functional groups such as pollinators, etc.). An opening measure and a closing measure for each column is recorded for the accounting period. Where possible, additions and reductions to those measures are also recorded whether due to unmanaged or managed changes. For example, additions could be due to species population growth, reintroductions or translocations.

13.34 A range of species accounts have been developed following the general principles outlined here. Examples include accounts for cycads and rhinoceros in South Africa (Statistics South Africa, 2021a, 2021b), accounts for butterflies in the Australian Capital Territory, and species accounts in the Netherlands (Bogaart et al., 2020).

Table 13.1: Species account for an Ecosystem Accounting Area

	Species or Species Group 1	Species or Species Group 2	Species or Species Group 3	Species or Species Group 4	Species or Species Group 5	Species or Species Group 6	Species or Species Group 7	Species or Species Group 8	Species or Species Group 9	Species or Species Group 10
UNITS OF MEASURE										
Opening measure										
Additions										
Unmanaged										
Managed										
Reductions										
Unmanaged										
Managed										
Net change										
Closing measure										

13.35 While there are a range of possible species accounts and associated extensions, species accounts can be linked to other accounting data through the use of aligned geographic boundaries, classifications and accounting treatments. Species accounts can therefore readily complement the other information, especially concerning economic activity and human well-being in accounting for biodiversity.

13.3.4 Accounting for habitats and spatial scale

13.36 As noted above, a common approach to the assessment of species in the absence of data on individual populations is to use data on the area and spatial configuration of habitat for species. Given that a relationship exists between habitat and ecosystem types, there is the potential to use data on ecosystem extent and ecosystem condition from the ecosystem accounts to support the derivation of habitat-based information both for individual species and in the context of assessing multi-species diversity. An example of this work is the accounting for Chimpanzees and Shea trees in Uganda (UNEP-WCMC & IDEEA, 2017) and accounting for multi-species plant, vertebrate and invertebrate diversity in the San Martin region of Peru (Alam et al., 2016). Further examining the potential connection between SEEA EA and habitat-based biodiversity assessment is one area of research in accounting for biodiversity. A background paper that discusses relevant issues, in particular with regard to addressing issues of spatial scale in deriving and aggregating biodiversity metrics, provides an appropriate framing for this area of research.[141]

13.37 In deriving complex measures of multi-species diversity, data on the abundance and trends of a selected species in individual locations will be relevant, but to measure species diversity it is also useful to understand species assemblages, i.e., where different local populations of multiple species exist and how they are connected to other local populations and in relation to different ecosystem types. Different species, and species assemblages, will perform different functional roles and have varying degrees of resilience to different pressures. Thus,

[141] The background paper "Addressing spatial scale in deriving and aggregating biodiversity metrics for ecosystem accounting" is available at: https://seea.un.org/content/accounting-biodiversity.

understanding the complementarity of species assemblages is a key long-term concern if ambitions for establishing resilient multi-functional landscapes are to be realized. This includes the maintenance of capacity for future ecosystem-service delivery at landscape (rather than ecosystem asset) scale.

13.38 These types of considerations of spatial scale in providing such complex measures of multi-species diversity are beyond the scope of ecosystem extent and condition accounts directly. In particular, since the focus of ecosystem accounts is on accounting for individual ecosystem assets, the information set will not capture to any degree the effects of spatial variation and complementarity in species composition across whole regions (i.e., beta and gamma diversity) or the effects of spatial configuration of habitat (e.g., connectivity) on biodiversity persistence. These aspects of biodiversity may be considered in accounting for biodiversity. An introduction to relevant concepts and methods on the relationship between ecosystem accounts and issues of spatial scale in the measurement of biodiversity is provided in an accompanying technical note.

13.3.5 Accounting for the genetic level of biodiversity

13.39 Genetic diversity concerns the variety of genes between and within species populations. Genetic diversity within species populations is linked to the condition of those populations. As meta-populations become fragmented and individual populations become isolated, exchanges of genetic material within the species are restricted. Further, as IPBES identifies, maintaining phylogenetic diversity[142] is important for maintaining options concerning genetic diversity overall (i.e., a gene pool). Maintaining gene pools is also important for various commercial activities. For example, in the further development of crops or livestock that are well-adapted to different and changing conditions, e.g., in response to climate change, and with respect to biosafety and biosecurity. There are also option values linked to gene pools associated with future medical applications or other bio-mimicry technologies and their development.

13.40 The basic framing of a species account shown in Table 13.1 could be adapted to support discussion of these issues by recording, for example, the extinction risk of phylogenetically diverse species or species groups. In addition, if the results can be presented with appropriate spatial detail, species accounts could be used to help track trans-locations of selected species where meta-populations become isolated (e.g., transfers of iconic species between protected areas).

13.41 While recognising the importance of genes and their diversity in underpinning ecosystem function and the flow of ecosystem services, the development of accounts for the genetic level of biodiversity has not yet been advanced. However, as data on genetic material for selected species becomes more widely available, the use of accounting to frame the connection to economic and human activity and well-being may be of relevance.

13.3.6 Using accounting data to support decision making on biodiversity

13.42 The SEEA EA supports discussion of the link between biodiversity and economic activity and human well-being by providing a description of the relationships between ecosystems, the species that comprise them, and the SNA and non-SNA benefits that ecosystems provide. Description of these relationships can be complemented by data from the SEEA Central

[142] Phylogenetic diversity reflects genetic differences between species with different evolutionary histories.

Framework, where the focus is on tangible material and financial flows about the environment and the economy (e.g., provisioning ecosystem services, pollutant emissions, environmental protection expenditure). Data on economic activity related to specific locations of interest may also be integrated using national accounting principles. Accordingly, across this suite of accounts, many aggregates and indicators are relevant to biodiversity at the ecosystem level and also to biodiversity at levels other than ecosystems. A non-exhaustive set of relevant indicators and aggregates are summarized in Table 13.2.

Table 13.2: Linking SEEA accounts to biodiversity at levels other than ecosystems

Framework	Account	Aggregate	Relevance
SEEA EA	Extent	Extent of Ecosystems	Trends in the extent of ecosystems important for biodiversity can be used to infer implications for species and species loss.[143] They also provide an insight into habitat loss, a key driver of biodiversity loss.
SEEA EA	Condition	Biotic characteristics	These can distinguish ecosystem assets in which biodiversity is more intact. For example, identifying areas of grassland with high values for species-based indicators or patches of forest with 'good' structural characteristics. They can also provide information on where biodiversity is threatened, based on trends of poor condition (e.g., invasive species abundance).
SEEA EA	Condition	Abiotic characteristics	These can track where pressures on biodiversity may be manifesting (e.g., where pollutant concentrations are increasing). They can help highlight and quantify potential relationships between ecosystem degradation and species loss, including through the use of habitat-based biodiversity assessment techniques.
SEEA EA	Services	Physical Supply and Use	Aggregates for provisioning services can identify where overexploitation of individual species is occurring (e.g., where sustainable yields are being exceeded). This can also include illegal use, such a poaching, where sustainable yield may be zero.
SEEA Central Framework	Land Use & Land cover	Areas of biodiversity impacting or enhancing activities	Data on land use, land use change and land cover allow information on spatial biodiversity loss to be linked to different sectors and economic activities.
SEEA Central Framework	Emissions Accounts	Spatially disaggregated emission flows	Emission flows can identify where pollutant pressures on biodiversity are likely to manifest. These insights are enhanced by (potentially) linking to spatially disaggregated accounts.
SEEA Central Framework	Environmental Protection Expenditure	Expenditure on biodiversity conservation and enhancement	Where these financial transactions can be linked to changes in ecosystem and species status or indicators of biodiversity at scale, they can have significant policy implications. In particular, they will be useful in understanding the ecological and economic benefits from public and private expenditure on the environment and biodiversity
SNA	Production and Consumption	Monetary transactions involving biodiversity related goods and services	A number of monetary aggregates relevant to biodiversity exist in the SNA (e.g., provisioning services, wildlife tourism, recreational activities in nature). These aggregates can also be linked to the elements of biodiversity supporting their supply via the SEEA EA. They can also inform on the opportunity costs for biodiversity conservation (e.g., revenues foregone). They can also inform on monetary trade-offs / opportunity costs associated with different management approaches for biodiversity.

13.43 Assuming that these various accounts can be compiled using aligned geographic areas, classifications and accounting treatments, a wide variety of cross cutting indicators and analysis can be derived from a coherent information set. For example, relationships might be

[143] Even without ongoing species monitoring, the species-area curve can reasonably estimate species loss based only on change in ecosystem extent.

analysed between expenditure on biodiversity and changes in ecosystem condition, and changes in condition might be assessed in relation to changes in land use and emissions.

13.44 Accounts showing the extent of ecologically important areas that support significant biodiversity will also provide useful information to supplement the information presented in Table 13.1. Such areas include those determined by, for example, policy designations (e.g., concerning Ramsar wetlands or the European Union Habitat Directive areas); scientific determinations (e.g., such as Key Biodiversity Areas (KBAs, including Alliance for Zero Extinction (AZE) sites); broad scale regional prioritizations (e.g., biodiversity hot spots identified by Conservation International; and national and sub-national government prioritisations and regulations. Similarly, compiling accounts showing the extent of important ecosystems for biodiversity within, and surrounding, protected areas is a relatively straightforward step in identifying where biodiversity is most at risk and where the risk of biodiversity loss should be managed. Ecosystem condition accounts record changes in several biodiversity related indicators which can also be used to understand trends in biodiversity.

13.45 The physical and monetary values presented in ecosystem service flow accounts can reveal to decision-makers the importance of species and their diversity, particularly in relation to provisioning services,[144] and ecosystems to economic activity (e.g., tourism) and well-being. In this way, data on ecosystem services may support the case for investment in biodiversity conservation and restoration. Publicly available information on the multiple ways in which ecosystems support well-being can inform more holistic planning approaches. For example, by encouraging nature-based solutions that benefit multiple sectors, can deliver better social outcomes and achieve conservation objectives.

13.46 One approach to the presentation of these different types of data is to use combined presentations following the principles outlined in the SEEA Central Framework. These presentations provide a means of bringing together information from various accounts to describe connections between the different components of biodiversity and wider economic and social statistics. In this way, they can be a useful tool for mainstreaming discussion of biodiversity. In particular, presenting trends about the extent and condition of ecosystems of high biodiversity value and their economic context can assist in making informed decision-making for biodiversity conservation. For example, it may be useful to present the opportunity costs of conserving mangrove forests and their biodiversity in terms of the forgone income from establishing shrimp farms in those locations. In these ways, multiple stakeholders in biodiversity can be mobilized and more cost-efficient solutions for delivering on economic and environmental objectives can be realized.

13.47 Some aspects of biodiversity that are essential for development to proceed in balance with nature may not be well-reflected in ecosystem service flow accounts. In general terms, this concerns the role that biodiversity plays in supporting the supply of ecosystem services as discussed in section 6.3.3. Two particular aspects concern insurance and option values.

13.48 Further, as noted in chapter 6, society also places significant value on the continued existence of biodiversity for spiritual, religious or non-use reasons. Related to this are existence values and bequest values. Thus, biophysical indicators will need to be used to reflect changes in the elements of biodiversity relevant to these types of values (e.g., extent of natural ecosystems, non-use flows recorded concerning ecosystems and species appreciation). Indicators from the species accounts will also be highly relevant.

[144] See for example, FAO (2019).

13.4 Accounting for climate change

13.4.1 Introduction

13.49 Climate change is one of the major global challenges of our time. Ecosystem accounting can provide data to understand the key role ecosystems play in greenhouse gas (GHG) cycling on global, national and regional scales that underpin the carbon concentration in the atmosphere. In addition, data from the ecosystem accounts can help understand the impact that climate change is having on ecosystems and biodiversity. This connection among ecosystems, climate change and biodiversity and the need to consider them jointly is recognised in the UNFCCC COP 25 decision that "underlined the essential contribution of nature to addressing climate change and its impacts and the need to address biodiversity loss and climate change in an integrated manner"[145] SEEA as an integrated statistical framework thus can play an important role in supporting international and national policy discussions related to climate change. Furthermore, it can provide the underlying data that links climate change to other environmental topics – e.g., biodiversity, circular economy.

13.50 The SEEA EA accounts in combination with the accounts from the SEEA Central Framework and SNA can support various aspects of climate change policy. These include carbon mitigation and adaptation policies, carbon markets and financing mechanisms, carbon stock assessment and management, linking air emissions and economic activity, recording and modelling climate change outcomes on ecosystems, ecosystem services and economic activity, sector based assessments (e.g., agriculture), ecosystem focused planning (e.g., peatlands), the co-benefits of carbon projects and policies, and the impacts of mitigation responses.

13.51 Thematic accounting for climate change complements existing measurement approaches described in the Intergovernmental Panel on Climate Change (IPCC) Guidelines in two ways. First, carbon emissions from terrestrial ecosystems result from *two processes*: human activities (management) and environmental change. The IPCC guidelines for GHG accounting have been developed to account for net emissions due to human activities whereas the SEEA EA is more comprehensive and includes both managed and unmanaged areas. Second, the SEEA allows making the connection with economic activities.

13.52 This section introduces how accounting can provide information to support decision making about climate change. Three aspects are considered: (i) the potential of data from the ecosystem accounts to inform decision making; (ii) accounting for stocks and changes in stocks of carbon; and (iii) other accounting connections and indicators. As for thematic accounting generally, the aim in this section is to introduce a range of connections to provide insight into the potential of accounting approaches.

13.4.2 Applying the SEEA EA to inform climate policies

13.53 Several of the ecosystem accounts provide data to support monitoring and analysis of climate change policies. In general, this connection emerges because of the impact that climate change has on the extent and condition of ecosystem assets and flows of ecosystem services. That is, the ecosystem accounts are a framework for recording a range of climate change effects on the environment and showing the links to economic and other human activity. By using a common framework for recording these effects, it is straightforward to compare the effectiveness of different policies aimed at mitigating or adapting to climate change.

[145] UNFCCC, Conference of the Parties, Twenty-fifth session, Madrid, 2–13 December 2019, FCCC/CP/2019/L.10. https://unfccc.int/sites/default/files/resource/cp2019__L10E_adv.pdf

13.54 The extent account shows the managed and unmanaged conversions in ecosystem types that directly underpin changes in carbon removal by, and emission from, ecosystems. Data from extent accounts can therefore be linked to the assessment of GHG emissions arising from LULUCF as used in IPCC measurements. The link between LULUCF and accounting is described in detail in the SEEA Agriculture, Forestry and Fisheries.

13.55 The condition account contains ecosystem characteristics and indicators that are highly relevant for climate change. Relevant physical state characteristics that relate to carbon stored in ecosystems include soil organic carbon, and dry matter productivity. Carbon stock indicators for biomass provide a direct link to the carbon stock account described below. Condition indicators should also capture the local impacts of climate change on ecosystem condition, for example the effects on local temperatures and rainfall patterns will be relevant in assessing condition in some contexts. Note however, that ecosystem accounts do not incorporate direct measurement of climate per se, for example in terms of atmospheric and ocean concentrations of GHG, or in terms of comprehensive data on temperatures and rainfall.

13.56 The reference list for selected ecosystem services (Table 6.3) includes several ecosystem services that are particularly relevant for climate change policies. Global climate regulation services are the ecosystem contributions to the regulation of the concentrations of gases in the atmosphere that impact on global climate, primarily through the sequestration and retention of carbon in ecosystems. The physical and monetary ecosystem service flow accounts (chapters 6, 7 and 9) show which ecosystem types play an important role in carbon sequestration and retention and how these change over time. Physical data on carbon retention and sequestration by ecosystem type are embodied in the carbon stock account described below.

13.57 Furthermore, there are several regulating ecosystem services that mitigate the effects of climate change. Local climate regulation services are the ecosystem contributions to the regulation of ambient atmospheric conditions. Examples include the evaporative cooling provided by urban trees and the contribution of trees in providing shade for livestock. Rainfall pattern regulation services are the ecosystem contributions of vegetation at the sub-continental scale, in particular forests, in maintaining rainfall patterns through evapotranspiration. Flood mitigation services, including both tidal surge and river flood mitigation, are the ecosystem contributions that mitigate the impacts of floods on local communities. Storm mitigation services are the ecosystem contributions of vegetation, especially linear elements in the landscape, in mitigating the impacts of wind, sand and other storms (other than water related events) on local communities. The accounts indicate what ecosystem types are the main contributors to reducing the effects of climate change, but also who the main beneficiaries are of these ecosystem services.

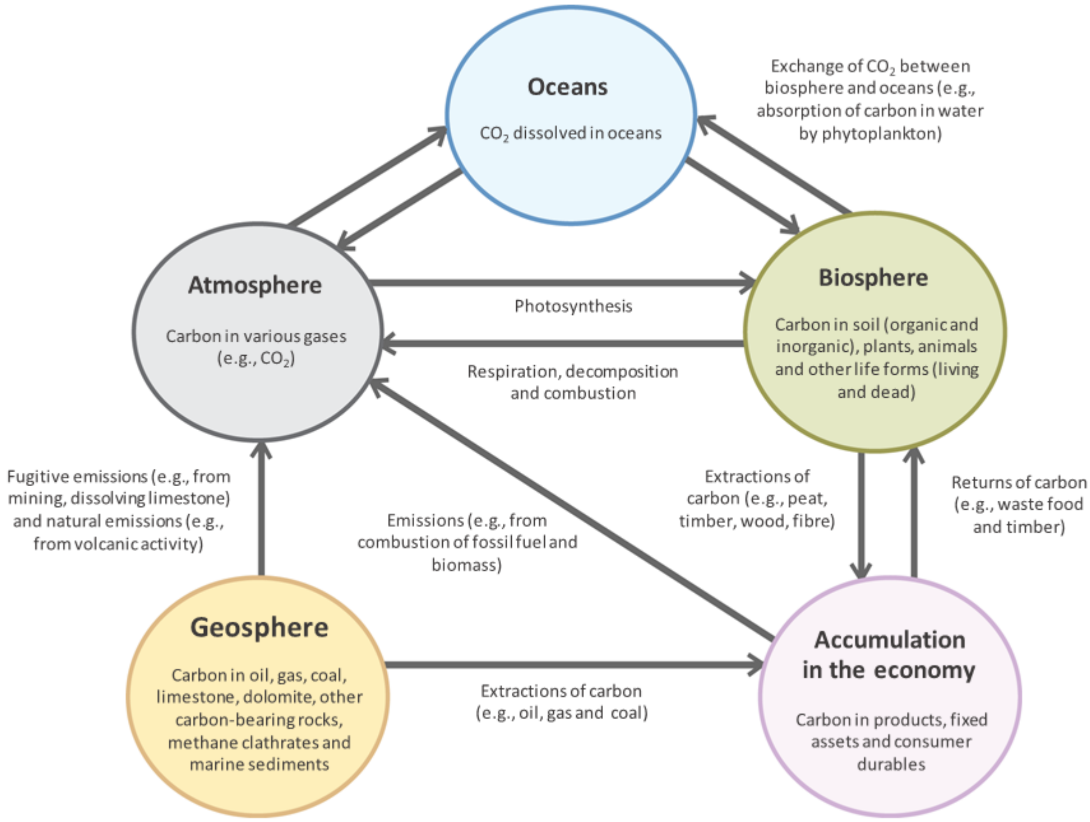
13.58 Finally, flows of several ecosystem services, including provisioning and cultural services, will be impacted by climate change e.g., water supply, biomass provision, recreation-related services etc, although isolating the precise contribution of climate change to the flows of ecosystem services is not the ambition in the accounts.

13.4.3 Accounting for carbon

13.59 Carbon has a central place in ecosystem and other environmental processes and hence accounting for carbon stocks and transfers between them is an important aspect of environmental-economic accounting. The carbon stock account provides a comprehensive coverage of all relevant carbon stocks and changes in stocks across all stores of carbon at a national or sub-national level covering both managed and unmanaged areas.

13.60 The fact that carbon plays an extensive role in the environment and the economy calls for a comprehensive approach to its measurement. Accounting for carbon must therefore consider stocks and changes in stocks of carbon of the geosphere, the biosphere, the atmosphere, oceans and the economy. Figure 13.1 presents the main components of the carbon cycle. It is these stocks and flows that provide the context for carbon accounting. The same accounting principles can also be applied to account for other GHG, including NO_x.

Figure 13.1: The main components of the carbon cycle



13.61 The structure of a carbon stock account is presented in Table 13.3. It provides a complete and ecologically grounded articulation of carbon accounting based on the carbon cycle and, in particular, the differences in the nature of particular carbon reservoirs. Opening and closing stocks of carbon are recorded, with the various changes between the beginning and end of the accounting period recorded as either additions to, or reductions in, the stock. A more detailed description of the carbon account is provided in annex 13.2.

13.62 Carbon stocks are disaggregated into: geocarbon (carbon stored in the geosphere), biocarbon (carbon stored in the biosphere, in living and dead biomass), carbon in the oceans (carbon dissolved in seawater, carbon in sediments is part of biocarbon or geocarbon), carbon in the atmosphere and carbon accumulated in the economy.

13.63 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 can be attributed between managed and unmanaged expansion and contraction. The net carbon balance equals addition to stock less reductions in stock.

13.64 All values in the carbon stock account should be in equivalent carbon weights (e.g., tonne carbon). Accordingly, methane (CH_4) and carbon dioxide (CO_2) emissions should be expressed in tonne carbon, not in the actual mass of CH_4 and CO_2. Similarly, for products like recycled plastic or paper, the equivalent carbon content should be determined, using the average composition of these materials to determine the carbon content. For emissions to the atmosphere, a bridge table may be compiled both in tonne carbon and in CO_2 equivalents, as the latter links to the SEEA Central Framework air emission accounts.

Table 13.3: Carbon stock account structure

	Geocarbon					Biocarbon			Carbon in the economy			Carbon in the oceans	Carbon in the atmosphere	Total
	Oil	Gas	Coal	Limestone and marl	Other	Terrestrial	Freshwaters and saline wetlands	Marine	Inventories	Fixed assets, consumer durables	Waste	Total	Total	
Opening stock														
Additions to stock														
Unmanaged expansion														
Managed expansion														
Discoveries														
Reclassifications														
Imports														
Reductions in stock														
Unmanaged contraction														
Managed contraction														
Reclassifications														
Exports														
Catastrophic losses														
Net carbon balance														
Closing Stock														

13.65 The carbon stock account complements other SEEA accounts. Although broader in coverage by including carbon stocks beyond ecosystems, carbon stock accounts are closely linked to the SEEA EA accounts. Carbon accounts can also provide information to support measures of the ecosystem services of carbon sequestration and carbon retention. They are also closely linked to accounts of the SEEA Central Framework (e.g., physical assets of fossil fuels and minerals, carbon emissions to air, physical product flows to and from the rest of the world). Finally, the SEEA AFF provides a detailed description of the links between these economic activities and emissions of carbon with a particular focus on the effects of LULUCF emissions.

13.66 The measurement of stocks and flows of carbon can support discussion of many policy relevant issues. These issues include the analysis of greenhouse gas emissions, sources of energy, deforestation and land use change, loss of productivity and biomass, and sources and sinks of carbon emissions. For example, carbon stock accounts can complement the existing flow inventories developed under the UNFCCC, including the Paris Agreement. Since carbon is also a common focus of policy response, for example carbon taxes, its direct measurement is of high relevance.

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

- Record the depletion of carbon stocks and the resulting CO_2 emissions due to conversion of natural ecosystems to other land uses.
- Prioritize use of land for restoration of biological carbon stocks through reforestation, afforestation, revegetation, restoration and improved land management, taking account of differing trade-offs in respect of ecosystem services, biodiversity, food, fibre and wood production.
- Identify land uses that result in carbon removal or retention.

13.4.4 Other climate change related accounts and indicators

13.68 Beyond the relevance of information from the ecosystem accounts and the carbon stock accounts, there are two other accounts that are highlighted. The SEEA Central Framework air emission account records the generation of air emissions by resident economic units by type of substance. These include the greenhouse gases CO_2, CH_4, N_2O and the F gasses. All emissions by establishments and households as a result of production, consumption and accumulation processes are included.

13.69 The GHG emissions by economic activities, as recorded in the SEEA, differ from the total emissions on a national territory or the emissions calculated according to the compilation guidelines of the IPCC. This is because different concepts and calculation methods underlie the different emission data. For instance, SEEA Air emission accounts include emissions due to international transport based on the residence of economic units involved. Bridge tables provide insight in the relations between the different emission concepts.[146]

13.70 Included in the scope of the SEEA Central Framework air emission accounts are emissions from cultivated livestock due to digestion (primarily methane), and emissions from soil as a consequence of cultivation and other land-use practices that affect soils, or other soil disturbances, such as a result of construction or land clearance. Emissions from natural processes, such as unintended forest and grassland fires, emissions from peatland, and also human metabolic processes are excluded. However, emissions from these sources are included in the carbon stock accounts.

13.71 In order to permit effective linking of physical flow data to monetary data, the physical flows of emissions are classified using the same activity and industry classifications used in the SNA. The emissions recorded for CO_2 end CH_4 in the SEEA Central Framework air emission account directly link to the removal (managed expansion) of carbon from the atmosphere and the emission (managed contraction) of carbon by the economy as recorded in the carbon stock account.

13.72 The SEEA CF environmental activity accounts record transactions in monetary terms between economic units that may be considered environmental. Generally, these transactions concern activity undertaken to preserve and protect the environment. Transactions in environmental activity accounts are classified by the classification for environmental activities (CEA). Two classes are particularly relevant for climate change: EP 1 Protection of ambient air and climate, which includes activities aimed at the control of emissions of greenhouse gases, and RM 10 Management of mineral and energy resources, which includes activities related to

[146] See for example Tables 5.2.1 and 5.2.2 in Lof et al. (2017).

energy saving and renewable energy production. Using data about these classes from the accounts supports analysis of the mitigation costs for climate change and the economic benefits that result from the energy transition with regard to labour and the contribution to GDP.

13.73 As well, there are a range of transactions, such as taxes and subsidies, that reflect efforts by governments, on behalf of society, to influence the behaviour of producers and consumers with respect to the environment. Payments and financial transactions relating to carbon taxes and emission permits are recorded in the SNA.

13.74 There is a wide range of indicators that may be derived from the various SEEA accounts concerning climate change. Examples include indicators of energy and emission intensity, indicators concerning carbon taxes and emission permits and indicators of expenditure on climate change related responses. The SEEA Applications and Extensions provides a range of guidance in this area, in particular concerning the potential to undertake relevant structural decomposition analysis and footprinting. This provides estimate of the emissions embodied in goods and services that are imported (and exported) thus showing production and consumption perspectives. There is also the potential for data from the accounts to support climate change modelling in terms of implications of projected climate change scenarios on economic activity.

13.75 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. There are also links that can be made to support the measurement of SDG 13 “Take urgent action to combat climate change and its impacts”.

13.76 One indicator that can be derived from the carbon stock account is the ‘net ecosystem carbon balance’ which can be used as the metric for measuring carbon sequestration. 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 carbon in other reservoirs. Also, in some contexts, and subject to appropriate assumptions, carbon carrying capacities may be estimated to support land use decision making where there are significant competing uses of land for food and fibre.[147]

13.5 Accounting for the ocean

13.5.1 Introduction

13.77 The Earth’s coastal and marine areas are an essential source of resources that support economic and other human activity while also being critical to the climate and the health of global ecosystems. However, demand for ocean space and resources, and associated anthropogenic pressures on ocean systems are increasing rapidly. In recent years, a growing number of countries have established ambitious policies and programs designed to accelerate both ocean-based development and conservation. Decision-makers are thus increasingly confronted with complex challenges and pressures to balance the social, environmental and economic interests of present and future generations. In this context, an integrated and standardized set of accounts that record ocean related measures of economic activity, social

[147] See for example H. Keith et al. (2010).

context, and ecosystem condition can support balanced decisions for near-term policy and long-term sustainability.

13.78 At the global level, 2021 marked the beginning of the Decade of Ocean Science,[148] declared by the International Ocean Commission of UNESCO. Further, UN Oceans is in the process of updating the First Global Ocean Assessment;[149] the OECD is continuing to support the assessment of the ocean economy;[150] and the High Level Panel for a Sustainable Ocean Economy[151] has developed an action agenda, including ocean accounts, for transitioning to a sustainable ocean economy. The IPCC also has recently focused specifically on oceans, releasing an assessment of the "Ocean and Cryosphere in a Changing Climate".[152] All of these initiatives have in common the need to integrate fragmented data and the objective of advising national governments on sustainable use of the ocean.

13.79 Conceptually, aspects of the ocean encompassing coastal and marine areas, are included in the SNA, SEEA Central Framework and SEEA EA. However, different measurement boundaries are applied across these frameworks. Further, data about the ocean is more fragmented than for terrestrial and freshwater ecosystems and the understanding of the ecological and economic connections among marine ecosystems, coastal ecosystems and other ecosystems is less advanced, although the relationship is expected to be highly non-linear. This requires a special focus to strengthen our understanding of ocean related areas, the governance of our activities that impact them, and the coordination of ocean data within and outside of national territories.

13.80 This section introduces the design of a set of ocean accounts. This design follows the general principles of thematic accounting in linking data from different accounts. It is assumed in this section that the various contributing accounts can be compiled in their own right, for example, extent and condition accounts for coastal and marine ecosystems (following the principles in chapter 5) and accounts on the flows of ecosystem services (following the principles in chapters 6, 7 and 9).

13.5.2 A set of ocean accounts

13.81 A comprehensive set of ocean accounts enables decision-makers to monitor several critical trends: (i) changes in ocean ecosystem extent and condition, and in associated flows of ecosystem services; (ii) changes in ocean wealth, including produced assets (e.g., ports) and non-produced assets (e.g., mangroves, coral reefs); (iii) ocean-related income and welfare for different groups of people—e.g., income from fisheries for local communities; (iv) ocean-based economic production—e.g., GDP from sectors deemed to be ocean-related; (v) changes in how oceans are governed and managed—e.g., ocean zoning, regulatory rules and responsibilities, and social circumstances.

13.82 These are important inputs to a range of ocean governance processes including marine spatial planning, integrated coastal zone management, development planning for ocean sectors, and collaborative resource management.

13.83 Building on the SEEA ecosystem extent, ecosystem condition and ecosystem service flow accounts, the Ocean Accounts Framework (Figure 13.2) adds accounts for natural resources

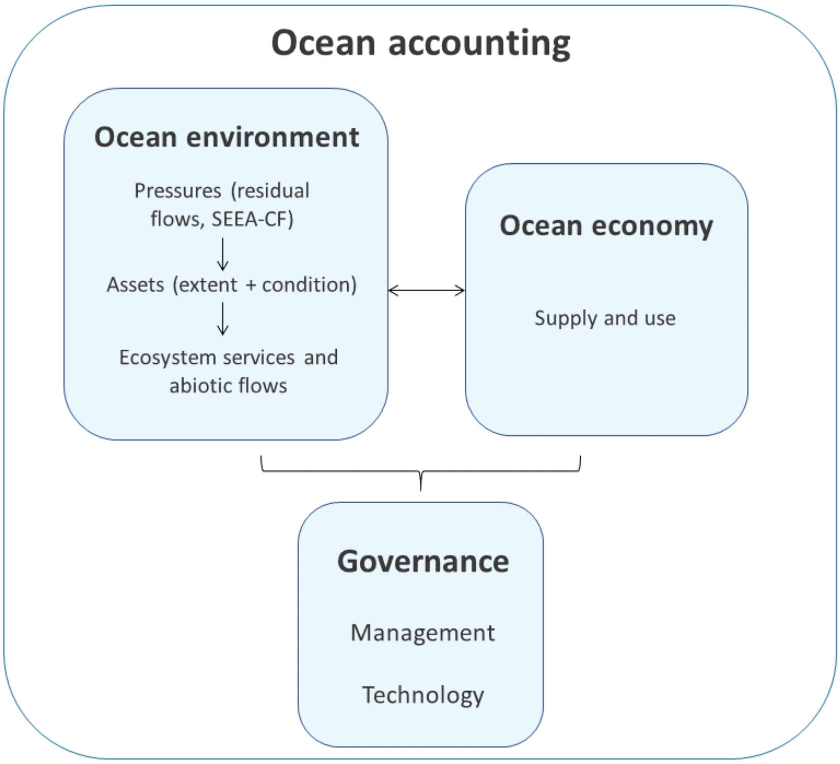
[148] See: https://en.unesco.org/ocean-decade.
[149] See: https://www.unenvironment.org/resources/report/first-global-integrated-marine-assessment-world-ocean-assessment-i
[150] See: http://www.oecd.org/ocean/topics/ocean-economy/
[151] See: https://www.oceanpanel.org/about-the-panel
[152] "Cryosphere" refers to areas of water that are frozen for at least part of the year. See: https://report.ipcc.ch/srocc/pdf/SROCC_FinalDraft_FullReport.pdf

and pressures on oceans from the SEEA Central Framework and accounts concerning the ocean economy, and concerning governance, management and technology.

13.84 Ocean assets are recorded in a combination of accounts for individual environmental assets (minerals, energy and aquatic resources, e.g., fish stocks) from the SEEA Central Framework and for ecosystem assets from the SEEA EA. Spatially located individual environmental assets are distinguished between terrestrial and marine realms. In developing ocean accounts for these assets, a particular focus will be needed on the treatment of migrating fish stocks and those assets beyond the EEZ whose management may not be captured in the accounts of the SEEA Central Framework or SNA.

13.85 Coastal and marine ecosystems are treated according to the SEEA EA. Extent and condition accounts describe these ecosystems and, for transitional ecosystems, such as estuaries and tidal flats, applying the IUCN GET provides a link to terrestrial and freshwater ecosystem accounts. In developing ocean accounts for these various ecosystem assets, challenges may lie in appropriately reflecting the three dimensions of marine areas (i.e. reflecting depth in addition to area) and accurately capturing changes in condition. Commonly, it will be beneficial to link measures of pressures on oceans (e.g., pollution) with direct measures of ecosystem condition. While data on pressures is important in understanding the connection to economic and human activity, direct monitoring of ocean condition is still required.

Figure 13.2: Coverage of Ocean Accounts Framework



13.86 Ocean services include ecosystem services and abiotic flows (e.g., mineral extraction and energy capture). There are many ocean ecosystem services including the provision of biomass (through wild fish and aquaculture), coastal protection and tidal surge mitigation, water purification, nursery population and habitat maintenance, recreation-related services and visual amenity services. These services supplied by coastal and marine ecosystems should be recorded in the ecosystem services flow accounts in physical and monetary terms.

13.87 The SEEA Central Framework provides guidance on measuring pressures on the ocean, particularly air emissions, water emissions and solid wastes. For ocean accounts, these are spatially detailed by catchment area to estimate the quantities flowing to the ocean.

13.88 The ocean economy is measured in terms of the contribution of the main ocean-related activities (marine transportation, coastal tourism, marine fishing, offshore minerals and gas, etc.) to the national economy. Following SNA guidance, the ocean economy can be accounted for using satellite accounting principles. At the core of ocean economy satellite accounts is the measurement of the contribution to GDP and Gross Value Added (GVA) of the sectors already in the SNA. More detail is added from estimates of the contributions of activities (e.g., shipping, boatbuilding, etc.) that are partially related to the ocean. Potentially, the economic value of ecosystem services not counted in these sectors (e.g., coastal protection services) could be added following the supply and use principles described in chapters 7, 9 and 11.

13.89 The objective of the ocean governance accounts is to provide spatially explicit, location-based information so that decision makers and planners can make the most effective decisions in ensuring the sustainable use of the ocean. The governance accounts include combined presentations of the elements mentioned above, but also explicit consideration of the institutional and legal frameworks such as zoning, rules and decision-making institutions, social circumstances of affected populations, and measures of ocean-related risk and resilience to them. One way in which these data may be combined is to overlay spatial data on different topics for a given marine or coastal area. This can show, for example, which ecosystem types are under different types of ocean management.

13.90 Much of the information required to compile ocean accounts is common to other communities of practice including marine spatial planning, disaster risk and climate change. One objective of the ocean accounting community of practice[153] is to ensure that these common data are standardized and shared.

13.91 Terrestrial and freshwater ecosystems are largely within national jurisdictions. However, the ocean is mostly beyond national jurisdictions (ABNJ or Areas Beyond National Jurisdiction). This raises the opportunity to compile global ocean accounts, where much of the data are already collected by international agencies. A Global Ocean Data Inventory[154] was compiled by the United Nations Economic and Social Commission for Asia and the Pacific and is organized using the components of the Ocean Accounts Framework. It shows that substantial data are available on ABNJ to compile ecosystem extent and condition accounts, but data on pressures, services, and beneficiaries are under-represented and hence additional data and monitoring is required. Adjacent coastal countries may also compile comparable ocean accounts to better understand transboundary impacts, including flows to and from ABNJ.

13.92 The ocean accounts framework has proven effective in supporting several pilot studies, each of which has aimed to answer policy-relevant questions. The pilot studies in Samoa, Thailand and Viet Nam centred around sustainable tourism by linking tourism income, natural resources use, land-based pollution, and ecosystem impacts. China's pilot focused on developing harmonised mangrove maps as well as improving the understanding of environmental assets of the mangrove ecosystems in Beihai Bay, one of China's important marine ecological sites. Malaysia examined food security risk (i.e., fish) along the Straits of Malacca under expected future climate variability. All pilots depended on available data which

---

[153] https://www.oceanaccounts.org/ and https://communities.unescap.org/environment-statistics/tools/regional-ocean-accounts-platform.

[154] http://communities.unescap.org/system/files/global_ocean_data_inventory_v1.0_text_20191213_compressed.pdf.

was often limited.[155] One important aspect of the Ocean Accounts Framework was to guide the search for, and integration of, the data.

13.5.3 Indicators derived from ocean accounts

13.93 Beyond sets of accounts, input to decision making may be best facilitated through the derivation of indicators. This general topic is discussed at length in chapter 14. These paragraphs provide a summary of the considerations from an ocean perspective.

13.94 In terms of ecosystems, the ocean maybe viewed as a set of marine, coastal, and transitional ecosystem types and any indictors derivable from the SEEA EA can also be derived from the ocean accounts. Nonetheless, with their specific focus, ocean accounts can provide specific indicators for ocean conditions such as acidification and concentrations of marine debris. Ocean accounts can also provide indicators for ocean-related beneficiaries, such as income of small-scale fishers.

13.95 Linking to the SEEA Central Framework allows for inclusion of indicators of sub-national sources of pressures (such as solid waste supply and use by catchment area), separate accounts for individual environmental assets for the ocean (such as marine fish and offshore oil and gas), and for accounts tracking environmental protection and other expenditures on the ocean.

13.96 The ocean economy satellite accounting component provides means to calculate the contribution of ocean-related sectors to national economies. As well, the focus on governance adds indicators on actors/institutions, norms and behavioural relationships. For example, knowing the location of ocean assets, the degree to which they are used and the designated use of that area, provides useful information for the management of that area. A listing of indicators derived from ocean accounts is presented in annex 13.3.

13.97 Of relevance in ecosystem accounting are scientifically supported statistics of ocean ecosystem condition. Examples of relevant characteristics are represented by different metrics in different ecosystems (Table 13.4) categorized by biodiversity, ecosystem fitness, biogeochemical cycling, physiochemical quality and GHG retention. The Global Ocean Accounts Partnership has been working with several ocean-related communities of practice, including oceanographers and ocean ecologists to produce a draft set of "Core Ocean Statistics". The Global Ocean Observing System (GOOS) is developing Essential Ocean Variables (EOVs) for biology which include biodiversity, and from which a number of Essential Biodiversity Variables (EBVs) could be derived for a number of groups of organisms and habitats (including those listed in Table 13.4). Examples can be found in Moltmann et al. (2019) and Muller-Karger et al. (2018).

[155] Pilot study reports can be found here: https://communities.unescap.org/environment-statistics/tools/ocean-accounts-national-pilots-3 and/or here: https://www.oceanaccounts.org/asia-pacific-community-of-practice/.

Table 13.4: Examples of potential Core Ocean Statistics for Biogeochemical Cycling

Ecosystem type					
Coral reef (M1.3)	**Mangrove (MFT1.2)**	**Kelp forest (M1.2)**	**Salt marshes and estuaries (FM1 Transitional freshwater-marine)**	**Sediment (M1 marine shelf and M3 deep sea)**	**Open Ocean (M2 pelagic ocean)**
Nitrate concentration	Soil Nitrogen	Nitrate Concentration	Sediment Redox Potential	Nitrate Concentration	Thermocline
Total Alkalinity	Turbidity	Ammonium Concentration	Hypersalinity	Sulphate Concentration	Pycnocline
Offshore: Inshore DIC ratio	Sediment Accumulation: Sea Level Rise ratio	Kelp Growth Rate	Inundation Depth	Sediment Redox Potential	Vertical Profile: Oxygen
Aragonite Saturation State	Particulate/Dissolved Organic C:N	Dissolved Oxygen Concentration	C:N Sediment ratios	Particulate/Dissolved Organic C:N	Vertical Profile: Nitrate
Dissolved Oxygen	Dissolved Oxygen	C13 Stable Isotopes	Submerged Plant Growth Form	Dissolved Oxygen	Vertical Profile: pH
pH (total scale)	Soil and Water pH	N15 Stable Isotopes		pH (total scale)	Vertical Profile: DIC

13.6 Accounting for urban areas

13.6.1 Introduction

13.98 Urban areas can occur in most terrestrial settings—whether highland or lowland, in forest, grassland, desert, tropical or tundra regions. They are defined chiefly by the presence of people and by their alteration of the underlying environment. They consist of a wide array of heterogeneous materials. Combinations of buildings (e.g., low- and high-rise building), impervious surface covers (e.g., roads and parking lots), vegetation (e.g., parks and sports fields), bare soil (empty lots and unattended garden plots) and water (e.g., wetlands and streams) are fundamental components of the urban ecosystem.

13.99 Accounting for ecosystem assets and services in urban areas is of increasing importance considering the large and growing proportion of the world population living in cities. Further, the high density of economic actors with varying perspectives on the use of the environment can create significant, local challenges for decision makers. In this context, the regular and integrated information organised within the SEEA framework provides a transparent approach to inform green urban development that delivers better outcomes for people and improves the ecological quality of urban environments.

13.100 Depending on the scale of underlying datasets and the aggregation level at which the accounts are compiled, urban ecosystem accounts can support various aspects of international, national, sub-national, and municipal level policy on urban areas such as strategic planning and policy setting; communication and awareness raising; economic accounting; urban planning including peri-urban and coastal development. The application of accounting could extend further to consider management of water resources, water treatment, regulating and maintenance services (e.g., local climate regulation, air filtration, flood mitigation), renewable energy sources and management of recreational opportunities.

13.101 Different motivations will exist for accounts at different scales. For example, accounts covering all urban areas across a country will focus on drawing out common features and ecosystem service flows, while accounts for a single urban area may focus on specific local issues, perhaps also encompassing complementary valuations. A general benefit of applying accounting principles, particularly at local scale, is the intent to integrate data on a consistent basis over time. This can help bring together the data that are commonly available in various one-off reports to better support decision making.

13.102 Urban ecosystem accounts with sufficient spatial detail (potentially down to property level resolutions) can provide data to support trade-off analysis or benefit-cost analysis for spatial planning and design of policy instruments such as ecosystem service users' charges. If ecosystem asset and condition mapping have sufficient resolution (e.g., individual tree canopy size and height) ecosystem accounts can also provide support for compliance monitoring and litigation of environmental damages (e.g., illegal tree felling).

13.103 This section introduces the development of urban accounts building on the general framing of ecosystem accounts and taking into consideration some specific factors of relevance in the measurement for urban areas.

13.6.2 A set of urban ecosystem accounts

13.104 Urban ecosystem accounts will encompass measures of extent and include data on associated condition variables and indicators (e.g., urban tree canopy cover, urban air quality) and related ecosystem services (e.g., local climate regulation, water regulation, recreation-related services).

13.105 While urban ecosystems are an ecosystem type included in the SEEA EA ecosystem type classification, the compilation of urban ecosystem accounts provides the opportunity for a more detailed accounting for urban area sub-types, for example highlighting urban green and blue space, within the broader framing provided by the IUCN GET which defines a broad ecosystem functional group covering urban ecosystems (Class T7.4). Also, different boundaries and spatial resolutions of basic statistical units and reporting units can also be considered in order to address different purposes.

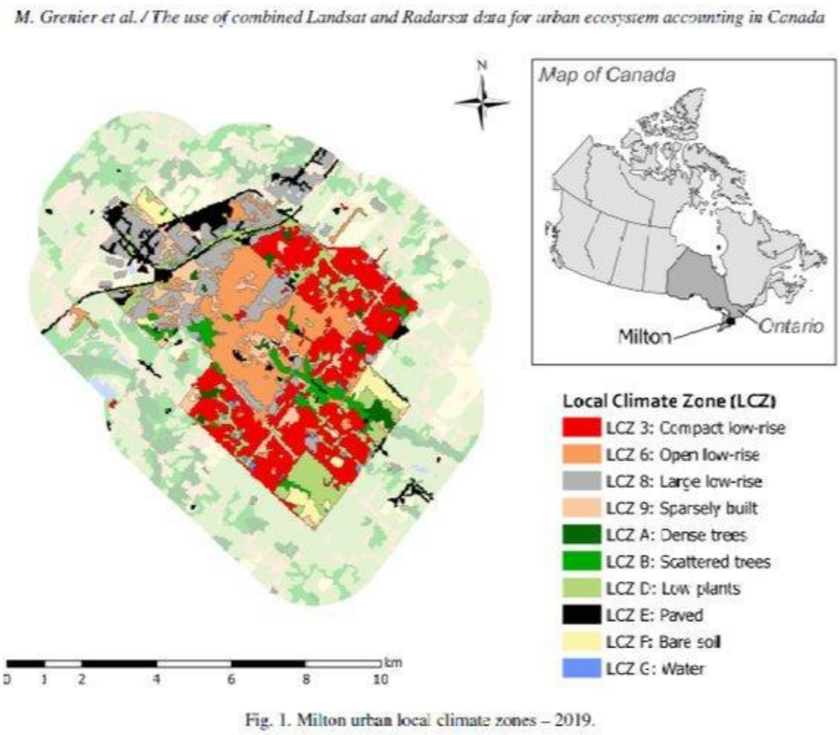
13.106 There are several approaches for defining the ecosystem accounting area for urban ecosystem accounts. Accounts can be compiled for cities based on administrative boundaries (i.e., local government boundary), functional boundaries (e.g., based on commuting flows as defined by census data), or morphological criteria, such as the extent of the built-up area plus a buffer zone. This selection will depend on the anticipated purpose and users of the urban accounts being compiled.

13.107 Urban areas often follow a gradient from less developed and even rural peripheral areas, into a more developed urban core. Even areas with a higher degree of built-up area may contain significant areas of urban green covers, such as yards, parks, cemeteries, street trees or green roofs. The two main approaches for the classification of urban areas into subtypes are (i) a landscape approach; or (ii) an individual asset approach.

13.108 Landscape approach: This approach disaggregates the entire urban area and categorizes larger patches with common characteristics, classifying these areas according to different urban sub-types. For example, a classification of urban sub-types could break down the variety of built-up and semi-natural types within the city into contiguous areas with common shared characteristics (e.g., compact high-rise, compact low-rise, open low-rise, sparsely built, paved as illustrated in Figure 13.3 and Figure 13.4). Following the landscape approach, information on condition characteristics (e.g., percentage of impervious/pervious surfaces, soil contaminant concentrations) could be included in the condition accounts as measures of landscape-level characteristics of these sub-classes. A landscape approach will tend to support municipal planning and zoning integrating across sector concerns.

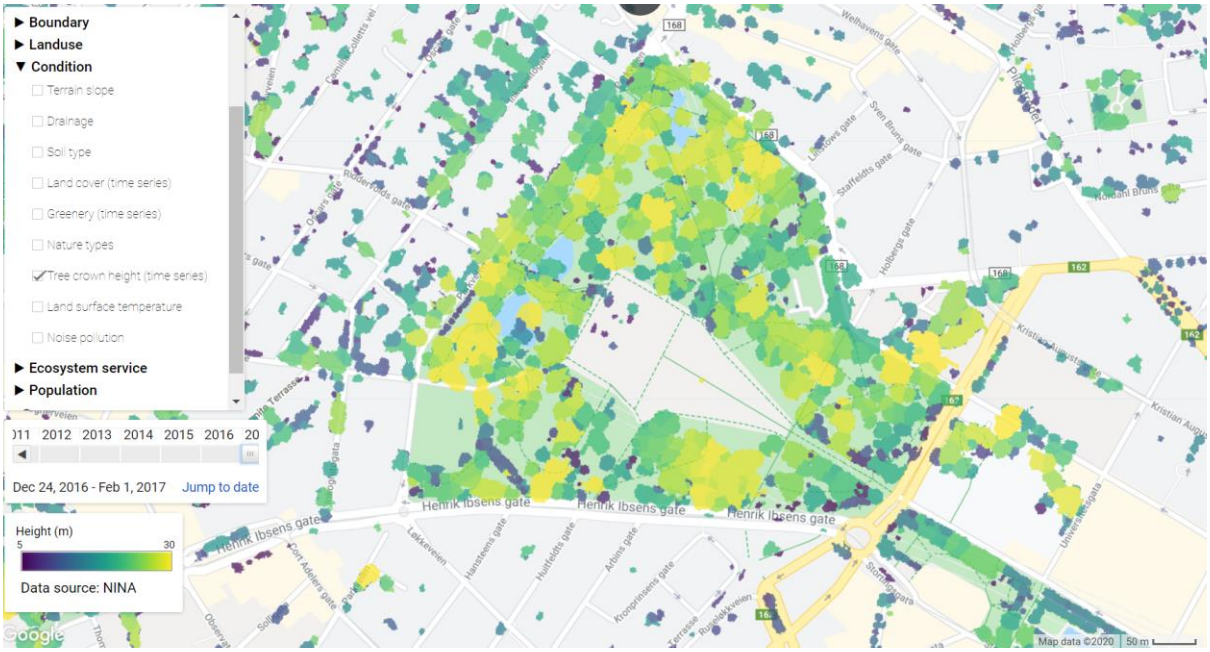
13.109 Individual asset approach: This approach tracks various individual asset types at as fine a scale as possible (e.g., lines of street trees, playgrounds, allotment gardens, green roofs, drainage and storage systems, etc.) based on available very high resolution (10 m or less) satellite imagery or other spatial data sets. In this case, ecosystem assets in urban accounts can be defined as areas of green and blue infrastructure that provide ecosystem services. This approach also permits reporting on the condition of these green/blue assets in the associated condition accounts. An asset approach tends to support thematic and sector policies specific to municipal sector agencies, such as urban forestry, urban agriculture, stormwater management.

Figure 13.3: Applying landscape approach for classifying urban ecosystems using Stewart & Oke (2009) local climate zone classification



Source: Grenier et al. (2020).

Figure 13.4: High resolution thematic focus mapping of urban tree canopy asset extent and height (condition)



Source: *Urban Nature Atlas Oslo* (2020).

13.110 The classification approach and level of aggregation will determine the distinction between extent accounts and condition accounts. Condition indicators that are predictors of urban ecosystem services should be selected. This does not prevent users from compiling thematic environmental quality and biodiversity indicators for other purposes. Extent table and condition table options following the landscape approach are shown in Table 13.5 and Table 13.6, whereas Table 13.7 provides an example of the individual asset approach.

13.111 In some contexts, it may be appropriate to distinguish the urban airshed as a separate asset.[156] This may support a distinct recording of air quality data as an overall condition indicator. However, generally it will be most appropriate to allocate measures of air quality to locations and areas within the wider urban area and hence a separate asset would not be required. Allocation to ecosystem assets within the urban area will also support measurement and modelling of ecosystem service flows such as recreation-related and amenity-related services.

13.112 Urban ecosystem service supply and use accounts may focus on a different basket of ecosystem services, given the differing functions and conditions of urban ecosystems as the physical place people live and work. Some key ecosystem services that will likely be considered include: water regulation, local climate regulation, air filtration, noise attenuation, recreation-related services and visual amenity services (Table 13.8).

[156] An airshed is a geographical area within which the air is frequently confined or channelled, with all parts of the area thus being subject to similar conditions of air quality.

Table 13.5: Example – extent account presentation using landscape approach

	Example ecosystem types in urban areas													
	Urban/built-up type and example sub-classes						Natural and semi-natural types							Total EEA
	Compact high-rise	Open high-rise	Compact low-rise	Open low-rise	Sparsely built	Paved	Cropland	Grassland	Shrubland	Forest	Barren	Wetland	Inland water	
Opening extent (km2)														
Additions to extent														
Reductions in extent														
Net change in extent														
Closing extent (km2)														

Table 13.6: Example – condition account presentation using landscape approach

		Example ecosystem types in urban areas																									
Example condition variables		Compact high-rise		Open high-rise		Compact low-rise		Open low-rise		Sparsely built		Paved		Cropland		Grassland		Shrubland		Forest		Barren		Wetland		Inland water	
Variables	Unit of measure	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock	Opening stock	Closing stock
Water quality	g/l																										
Air pollutant concentrations	ppm																										
Soil contaminant concentrations	g/kg																										
Soil sealing / Imperviousness	%																										
Greenness	%																										
Canopy cover	m^2																										
Street trees	km																										

Table 13.7: Example – extent account presentation using the individual asset approach

	Example ecosystem types and assets in urban areas																		
	Example urban ecosystem assets									Natural and semi-natural types								All other (grey) areas	**Total EEA**
	Allotment garden	Street trees	Sports field	Playground	Cemetery or religious grounds	Public park or garden	Green roof	Private green space (e.g., yards)	Beach	Cropland	Grassland	Shrubland	Forest	Barren	Wetland	Inland water	Total		
Opening extent (km2)																			
Additions to extent																			
Reductions in extent																			
Net change in extent																			
Closing extent (km2)																			

Table 13.8: Example – service account presentation using landscape approach

Example list of services	Unit of measure	Urban/built-up type and example sub-classes: Compact high-rise	Open high-rise	Compact low-rise	Open low-rise	Sparsely built	Paved	Natural and semi-natural types: Cropland	Grassland	Shrubland	Forest	Barren	Wetland	Inland water	Total EEA
Provisioning services															
Crops															
Regulating services															
Water regulation															
Climate regulation															
Air filtration															
Noise regulation															
Cultural services															
Recreation															
Amenity services															

13.113 There are a range of issues and limitations that should be considered in the measurement of urban ecosystem services that differ compared to other ecosystem types. For example, accurate change detection at the small spatial scales inherent in urban areas will be particularly important given that areas of change can be finer than the precision of the land cover classification used as input to ecosystem service models. Substitution possibilities between ecosystem services and man-made services will be more apparent in urban areas. As well, spatial patterns in urban ecosystem service supply are driven by biophysical variation in ecosystem conditions, while spatial variation in demand (e.g., due to changes in the location and movement of the population) may not be detectable at the same resolution. Heterogeneous use factors—related to population density, socio-economic and cultural diversity in cities, as well as substitution possibilities, qualitative values and non-linear distance decay of benefits can result in variations in beneficiaries and valuation results, particularly for recreational and amenity services.

13.114 For applications at municipal levels, urban ecosystem accounts need to align closely with the way municipal environmental administration is organized in order to address both integrated and sector specific municipal policy and planning needs. For this reason, a combined landscape and asset approach will often be required.

13.115 In some situations, for example cost benefit analysis of zoning and user charges, monetary valuation of ecosystem service supply and use by landscape types and calculation of asset values is undertaken. Monetary accounts at exchange values may also provide support for municipal budget allocation to asset investment and maintenance, for example in relation to green and blue infrastructure and nature-based solutions. It may also be necessary to consider the application of complementary values in providing a wider assessment of social benefits arising from different policies.

13.116 Where monetary valuation is undertaken for municipal level applications, higher temporal and spatial resolutions and change detection is required compared to the requirements for national level accounts. This may be addressed using different methods, for example by pooling data across a large number of decision-making units. With this in mind, monetary urban ecosystem accounts will therefore often need to be thematic and policy purpose specific (Gómez-Baggethun & Barton, 2013).

13.6.3 Potential indicators for urban ecosystems

13.117 Certain indicators can provide useful summary-level information on the state and condition of urban areas. For example, the change in extent of areas converted from natural or semi-natural ecosystem types to residential areas with associated infrastructures, tracked over time, provides a snapshot of urban expansion and the loss of natural and semi-natural areas. Other related indicators could focus on the concept of land degradation (e.g., percentage of contaminated or brownfield areas and reclaimed areas). Indicators drawn from these accounts can also track the role urban green and blue spaces play in providing ecosystem services, including moderating air and water pollution and mitigating heat islands, and can support the measurement of accessibility to green and blue spaces.

13.118 Thus, urban ecosystem accounts provide information that is relevant at many levels including for reporting internationally, nationally and at sub-national levels. For example, the change in extent and condition of lands converted to residential areas with associated infrastructures is relevant for SDG 15.3.1 Proportion of land that is degraded over total land area. As well, ecosystem accounting for urban areas is particularly relevant for SDG 11: Sustainable Cities and Communities, including for the following indicators (UN-Habitat, n.d.; UNSD & UNEP-WCMC, 2019):

- Indicator 11.3.1: Ratio of land consumption rate to population growth rate;
- Indicator 11.4.1: Total per capita expenditure on the preservation, protection and conservation of all cultural and natural heritage, by source of funding (public, private), type of heritage (cultural, natural) and level of government (national, regional, and local/municipal);
- Indicator 11.6.2: Annual mean levels of fine particulate matter (e.g., PM2.5 and PM10) in cities (population weighted); and
- Indicator 11.7.1: Average share of the built up area of cities that is open space for public use for all, by sex, age and persons with disabilities.

13.119 Beyond their use for these broad indicators, the use of ecosystem accounts to support municipal planning and policy analysis, for example related to the equitable distribution of municipal (ecosystem) services, will require disaggregation of statistics to different administrative areas such as districts, councils, boroughs or census tracts.

Annex 13.1: SEEA Central Framework accounts for individual stocks and flows

Introduction

A13.1 The SEEA Central Framework describes a range of different accounts for recording individual stocks and flows. There are two main types of account structures that are used –physical flow accounts (in the form of supply and use tables) and asset accounts, both of which may be compiled in physical and monetary terms. This section provides a brief summary of these accounts and describes how they can be adapted to support compilation of ecosystem accounts and thematic accounts.

Physical flow accounts

A13.2 The general principles of physical flow accounts are described in SEEA Central Framework Chapter 3. Account structures for five physical flows are provided: water, energy, air emissions, emissions to water and solid waste. Depending on the type of substance, these accounts describe flows from the environment to the economy, within the economy, and from the economy to the environment. They are primarily designed to record the connections between each type of substance and various economic units and hence are well aligned with objectives, such as footprinting, where the use of specific substances can be traced through economic activities and products.

A13.3 In concept, the principles of physical flow accounting can be used to record flows for all, elements, substances and materials. Examples include flows of nitrogen, phosphorus, heavy metals and carbon at an elemental level, and economy-wide material flows (all measured in mass) at a macro scale. The main requirement in applying accounting principles is that the same unit of measure is applied within a single account – e.g., tonnes, cubic metres.

A13.4 For SEEA Central Framework purposes, the description has a focus on measuring flows for each substance at a national level and thus integrating with national level measures of economic activity. Macro indicators concerning issues such as water use in agriculture, energy use in manufacturing and air emissions from the transport industry are thus readily derivable.

A13.5 For use in ecosystem and thematic accounting, there will be a need to the scope of the accounts described in the SEEA Central Framework to align with the requirements in terms of geographical area, spatial detail and economic units. For example, if there was interest in ocean accounting to understand emissions to marine areas, an adjusted flow account would follow the same general framing of the physical flow account for emissions to water but would require additional detail concerning the location of the emissions – i.e., providing a breakdown of the SEEA Central Framework entry for flows to the environment by location, e.g., by catchment (see SEEA Central Framework, Table 3.8). Additional detail might also be incorporated on the industries generating the releases to water and on the types of emissions.

Asset accounts

A13.6 Asset accounts are described in SEEA Central Framework Chapter 5. They are presented for land use and land cover and for a range of natural resources including mineral and energy resources, soil resources, timber resources, fish and other aquatic resources and water resources. The general logic is to record, in physical or monetary terms, the opening and closing stocks of the relevant individual resource and then the various additions and reductions in stock, including regeneration and depletion. The relevant accounting identity is that the opening stock plus additions less reductions must equal the closing stock.

A13.7 For thematic accounting, the principles of asset accounting are applied in the description of species accounts and carbon accounts in the sections above. The same principles can be applied to any individual stock to support both thematic and core ecosystem accounting. For example, an asset account for key fish species by location might be used to support compilation of ecosystem services flow accounts.

A13.8 As for the physical flow accounts, having selected a single type of stock, the key requirement in applying asset accounting principles is establishing the geographical area to which the account relates. This may be small or large but needs to be clearly defined such that the focus of measurement is clear and that linkages can be made to other data. It may be relevant to cross-classify data on the opening and closing stocks by types of area within the wider accounting area. For example, stocks of carbon might be cross-classified by ecosystem type.

A13.9 For ecosystem accounting purposes, in addition to carbon and species accounts, the asset account of most relevance is the water resources asset account, described in SEEA Central Framework section 5.11. This account records the opening and closing stocks of water for various types of inland water bodies including lakes, rivers and streams and groundwater. It then records additions to the stock of water through precipitation, inflows and transfers between other water bodies and returns from the economy; and reductions in stock due to abstraction by economic units, evaporations and outflows (e.g., to the sea) and transfers to other water bodies.

A13.10 The stocks and flows recorded in the water resources asset account document comprehensively the hydrological cycle as it pertains to inland water resources. Flows related to wastewater are also captured. Since stocks and flows of water are important aspects in understanding ecosystem condition and ecosystem services, there is likely to be significant relevance in the compilation of water resources asset accounts to support the compilation of ecosystem accounts.

A13.11 The measurement challenge to overcome is the need for ecosystem accounting to have data compiled at a relatively high level of spatial detail. This is possible through standard hydrological modelling which is commonly used to underpin the measurement of a range of ecosystem services including water regulation, flood mitigation and soil erosion control. The task therefore is to adapt the framing provided in the SEEA Central Framework to suit a higher level of spatial detail – in particular incorporating more detail on transfers of water between different parts of a catchment or water body. Ecosystem account compilers are encouraged to work with hydrological modellers to compile detailed water resources asset accounts, in part because the accounts can be a useful tool in ensuring coherence in water modelling between opening and closing stock positions.

Annex 13.2: Additional detail concerning accounting for carbon

A13.12 The rationale for carbon stock accounting in the context of ecosystem accounting was discussed in section 13.4. The present annex provides some additional details on the structure and accounting entries related to the carbon stock account as presented in Table 13.3. The carbon stock account presented in that table provides a complete and ecologically grounded articulation of carbon accounting based on the carbon cycle and, in particular, the differences in the nature of specific carbon reservoirs. Opening and closing stocks of carbon are recorded, together with the various changes occurring between the beginning and end of the accounting period recorded as either additions to or reductions in the stock.[157]

A13.13 Carbon stocks are disaggregated into geocarbon, biocarbon, carbon accumulated in the economy, carbon in the oceans (inorganic only) and carbon in the atmosphere.

A13.14 Geocarbon includes all carbon stored in the lithosphere, excluding all organic carbon stored in dead biomass.[158] Basically, carbon that is part of the Earth's lithosphere is considered as geocarbon (or geological carbon: carbon present in the Earth's bedrock and sediments, primarily from marine sediment deposits), as well as carbon formed originally in the Earth's biosphere millions of years ago, that, after geological metamorphosis due to high pressure and temperatures in the Earth's crust, was transformed into, for example, oil and gas (organic geocarbon). Organic carbon in soils and in peat deposits is included in biocarbon.[159] Where the information generated from the accounts is policy-focused, the priority should be given to reporting those stocks that are being impacted by human activity (e.g., fossil fuels).

A13.15 Biocarbon includes all organic carbon in the biosphere, i.e., carbon in living biomass (plants and animals) and dead biomass (soil organic matter and sedimentary organic matter).[160] Biocarbon includes biomass in crops, grass in meadows, which is thus not considered as carbon accumulated in the economy. Carbon stored in livestock, however, is considered as part of 'carbon in the economy'. Carbon stored in timber products, including timber used for construction, is also included as part of 'carbon in the economy'.

A13.16 Biocarbon is classified by type of ecosystem, at the highest level according to the three main realms of the IUCN GET (marine, freshwaters and saline wetlands, terrestrial). These high-level classes can be further broken-down using level 3 of the IUCN GET. It is recommended to separately record carbon in agricultural and other anthropogenic systems, to allow the distinction between carbon removal and emissions between natural and semi natural ecosystems and anthropogenic ecosystems.

A13.17 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 (Thompson et al., 2009). Stability confers longevity and hence the capacity for natural ecosystems to accumulate large amounts of carbon over centuries to millenniums, for example, in the woody stems of old trees and in soil. Semi-modified and highly modified ecosystems are generally less resilient and less stable (Thompson 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.

[157] Examples of carbon stock accounts include H. Keith et al. (2021) and Lof et al. (2017).

[158] Geocarbon is further disaggregated into oil, gas, coal resources, rocks (primarily limestone and marls), and minerals, e.g., carbonate rocks used in cement production, methane clathrates and inorganic carbon in marine sediments

[159] Soil is the layer of fine material covering the Earth's land surface influenced by and influencing plants and soil organisms.
[160] For biocarbon in soils, for practical reasons only the top 30 cm were included in this study. In particular for peat and peaty soils, this results in a strong underestimation of the total stock of biocarbon in soils. This shortcoming in the current models also potentially influences C flows in the case of water table changes exceeding this depth.

A13.18 The atmosphere contains carbon mainly in the form of CO_2 and methane. The atmosphere is a receiving environment with regard to carbon from the primary reservoirs geocarbon and biocarbon but also from emissions of carbon from the economy. On the other hand, carbon removal from the atmosphere may take place by carbon sequestration in biocarbon. As CO_2 and methane act as greenhouse gasses in the atmosphere, accounting for these flows is highly policy relevant.

A13.19 The oceans are the receiving environments for carbon released from primary reservoirs and its accumulations in the economy. Carbon in oceans includes only inorganic carbon: carbonates dissolved in seawater. Living and non-living organic carbon in oceans is part of biocarbon. Carbonate particulates (e.g., shells) in sediments are part of geocarbon.

A13.20 Accumulations in the economy, which are the stocks of carbon in anthropogenic products, are further disaggregated into the following SNA components: fixed assets (e.g., concrete in buildings, bitumen in roads, livestock); inventories (e.g., petroleum products in storage, excluding those included in cultivated ecosystems); consumer durables (e.g., wood and plastic products); and waste. In turn, these main asset categories can be further disaggregated into biobased (i.e., derived from plants or animals) and non-biobased (i.e., fossil fuels, mineral (inorganic) products and synthetic materials (plastics)). Accounting for waste follows the conventions of the SEEA Central Framework, where waste products (e.g., disposed plastic and wood and paper products) stored in controlled landfill sites are treated as part of the economy.

A13.21 The flows of carbon that occur within the economy are very significant and essential for understanding the interaction between economy and environment. The level at which geocarbon and biocarbon stock changes can be linked to the economy will determine the policy usefulness of the carbon stock account. This is particularly relevant in cases where raw materials can be extracted from different ecosystem types (e.g., biomass fuel from natural ecosystems or cultivated ecosystems) or from geocarbon reservoirs with different carbon contents and emissions profiles.

A13.22 Carbon stored through geo-sequestration (i.e., the managed injecting of gaseous CO_2 into the surface of the Earth) is treated similarly, as a flow within the economy (resulting in an increase in accumulations). Any subsequent release of carbon to the environment is treated as a residual flow with a reduction in accumulations in the economy matched by a corresponding increase in carbon in the atmosphere.

A13.23 The presentation of the row entries in the account follows the basic form of the asset account in the SEEA Central Framework; the entries being opening stock, additions, reductions and closing stock. Additions to and reductions in stock have been split between managed and unmanaged expansion and contraction. Additional rows for imports and exports have been included, thus making the table a stock account, as distinct from an asset account.

A13.24 There are five types of additions in the carbon stock account:

- Unmanaged expansion, which reflects increases in the stock of carbon over an accounting period due to natural growth or the indirect effects of human activities. Effectively, this will be recorded only for biocarbon and may arise from climatic variation, ecological factors such as reduction in grazing pressure, and indirect human impacts such as the CO_2 fertilization effect (where higher atmospheric CO_2 concentrations cause faster plant growth).
- Managed expansion, which reflects increases in the stock of carbon over an accounting period due to direct human activities. This will be recorded for biocarbon in ecosystems and accumulations in the economy, in inventories, consumer durables, fixed assets and waste stored in controlled landfill sites, and also includes greenhouse gases injected

into the earth. Basically, these reflect all increases in carbon stock due to carbon input flows from other reservoirs which are directly related to human activities. All emissions related to LULUCF are included here (or in managed contractions depending on the carbon stock).

- Discoveries of new stock, encompassing the emergence of new resources added to a stock, which commonly arise through exploration and evaluation. This applies exclusively to geocarbon.
- Reclassifications of carbon stocks, which will generally occur in situations where an ecosystem asset is used for a different purpose. For example, increases in carbon in semi-natural ecosystems following the establishment of a national park on an area previously used for agriculture would be offset by an equivalent decrease in cultivated ecosystems. In this case, it is only the particular land use that has changed, that is, reclassifications may have no impact on the total physical quantity of carbon during the period in which they occur.
- Imports are recorded to enable accounting for imports of produced goods (e.g., petroleum products) that contain carbon.

A13.25 There are five types of reductions recorded in the carbon stock account:

- Unmanaged contractions, which reflect natural losses of stock during the course of an accounting period. They may be due to changing distribution of ecosystems (e.g., a contraction of natural ecosystems) or biocarbon losses that might reasonably be expected to occur based on past experience. Unmanaged contraction includes losses from episodic events including drought, some fires and floods, and pest and disease attacks, and also includes losses due to volcanic eruptions, tidal waves and hurricanes.
- Managed contractions, which are reductions in stock due to direct 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 is recorded net of those quantities of stock that are immediately returned to the environment after extraction because they are unwanted—for example, felling residues. Managed contraction also includes losses as a result of a war, riots and other political events; and technological accidents such as major toxic releases. All emissions related to LULUCF are included here (or in managed expansions depending on the carbon stock).
- Reclassifications of carbon stocks, which generally occur in situations where another environmental asset is used for a different purpose. For example, decreases in carbon in cultivated ecosystems following the establishment of a national park on an area used for agriculture would be offset by an equivalent increase in semi-natural ecosystems. In this case, it is only the particular land use that has changed; that is, reclassifications have no impact on the total physical quantity of carbon during the period in which they occur.
- Exports are recorded to enable accounting for exports of produced goods (e.g., petroleum products) that contain carbon.
- Catastrophic losses, which are not shown as a single entry but are allocated between managed contraction and unmanaged contraction. Catastrophic losses in managed contraction would include fires deliberately lit to reduce the risk of uncontrolled fires. For the purposes of accounting, reductions due to human accidents, such as rupture of

oil wells, would also be included under managed contraction. Catastrophic losses could, however, be separately identified.

Annex 13.3: Variables and indicators from ocean accounts

	Ocean-related biomes [Note h]										
	SM1 Subterranean tidal biome	FM1 Transitional waters biome (Freshwater Marine)	M1 Marine shelf biome	M2 Pelagic ocean waters biome	M3 Deep sea floors biome	M4 Anthropogenic marine biome	MT1 Shorelines biome	MT2 Supralittoral coastal biome	MT3 Anthropogenic shorelines biome	MFT1 Brackish tidal biome	Total
Physical ocean assets											
Ecosystem assets											
Area (ha)											
Change in area from previous accounting period (%)											
Individual environmental assets											
Minerals (tonnes)											
Energy (PJ)											
Fish (tonnes)											
Timber (e.g., mangrove) (m^3)											
Other flora available for harvesting (e.g., seaweed) (tonnes dry weight)											
Monetary ocean assets (NPV of expected flow of services) (currency units)											
Ecosystem assets											
Value (currency units)											
Change in value from previous accounting period (%)											
Individual environmental assets											
Minerals											
Energy											
Fish											
Timber (e.g., mangrove)											
Other flora available for harvesting (e.g., seaweed)											
Condition of ocean assets [Note a]											
For marine and coastal ecosystems											
Acidification (pH)											
Eutrophication (BOD, COD, Chlorophyll-A concentrations)											
Temperature (°C)											
Plastics density (g/m^3)											
Biodiversity (Shannon index)											
Health (index)											
For individual environmental assets											
Minerals (quality, accessibility)											
Energy (quality, accessibility)											
Fish (quality in terms of size, age, health)											
Timber (e.g., mangrove) (quality, accessibility)											
Other flora available for harvesting (e.g., seaweed) (quality, health)											
Physical ocean services											
Ocean ecosystem services											
As in SEEA-EA services list (specific units)											
Other ocean services (examples)											
Seawater for cooling (m^3)											
Sand (tonnes)											
Petroleum (megalitres, PJ)											
Monetary ocean services											
Ocean ecosystem services											
As in SEEA-EA services list (appropriate valuation techniques)											

	Ocean-related biomes [Note h]										
	SM1 Subterranean tidal biome	FM1 Transitional waters biome (Freshwater Marine)	M1 Marine shelf biome	M2 Pelagic ocean waters biome	M3 Deep sea floors biome	M4 Anthropogenic marine biome	MT1 Shorelines biome	MT2 Supralittoral coastal biome	MT3 Anthropogenic shorelines biome	MFT1 Brackish tidal biome	Total
Other ocean services (examples)											
Seawater for cooling (market or equivalent value)											
Sand (market or equivalent value)											
Petroleum (market or equivalent value)											
Pressures (Flows to the environment) [Note b]											
Water emissions flows to the ocean											
BOD/COD (tonnes)											
Suspended solids (tonnes)											
Bilge (m^3)											
Heavy metals (tonnes)											
Solid waste flows to the ocean											
Chemical and health care waste (tonnes)											
Metallic waste (tonnes)											
Mineral waste and soil (tonnes)											
Mixed residential and commercial waste (tonnes)											
Plastics (tonnes)											
Radioactive waste (tonnes)											
Other waste (tonnes)											
Wastewater flows to the ocean (m^3)											
Air emissions flows to the ocean (examples) [Note c]											
CO_2 (tonnes)											
Methane (tonnes)											
Ocean economy											
Contribution of ocean sectors to the national economy (GVA, %GDP) [Note d]											
By sector (fishing/aquaculture, offshore oil and gas, boat and ship building, etc.)											
Contribution of ocean sectors to the national employment (FTE, %)											
By sector (fishing/aquaculture, offshore oil and gas, boat and ship building, etc.)											
Ocean governance											
Zoning											
Jurisdictional zone: internal waters, territorial sea, EEZ (area)											
Management or planning zone: protected area, private property, use designation (area) [Note e]											
Rules and decision-making institutions											
By activity: fishing, wind farm development, marine spatial planning (institution)											
Social circumstances of resident populations (examples) [Note f]											
Health (index), economic equity (GINI), poverty (% below low income)											
Risk and resilience (examples)											
Flood/storm surge, sea level rise, coastal storm risk (vulnerability, occurrence)											
Resilience: disaster plan in place, adequate supplies and facilities (yes/no)											
Environmental protection expenditures ($)											

	Ocean-related biomes [Note h]										
	SM1 Subterranean tidal biome	FM1 Transitional waters biome (Freshwater Marine)	M1 Marine shelf biome	M2 Pelagic ocean waters biome	M3 Deep sea floors biome	M4 Anthropogenic marine biome	MT1 Shorelines biome	MT2 Supralittoral coastal biome	MT3 Anthropogenic shorelines biome	MFT1 Brackish tidal biome	Total
Value of environmental goods and services sector ($, see Ocean Economy) [Note g]											
Environmental taxes less subsidies ($)											

Notes:

a: The Technical Guidance for Ocean Accounting provides specific condition indicators for each ecosystem type.

b: Flows should include generation by terrestrial catchment area, marine sources, inflows from other territories, outflows to other territories (including international waters)

c: Air emissions should be estimates of quantities deposited in the ocean, distinguished by national and international territory

d: The Ocean Accounts Framework provides a comprehensive list of ocean-related sectors. Economic activities could be located by ecosystem type.

e: Other examples of "use designation" is aquaculture, energy development, submarine cable corridor, locally managed marine area, etc.)

f: Resident population includes those dependent on the ocean economy and those living near the ocean.

g: The environmental goods and services sector may be embedded in the Ocean Economy as ocean dependent sectors. It may also be distinct if disaggregated from national EG&S surveys.

h: Indicators may be presented for larger groupings or in more detail by ocean-related Ecosystem Functional Groups. Note there may be vertical overlap of some of the biomes (e.g., subterranean tidal biomes with shoreline biomes). In this case, ideally, the indicators would be presented separately for the intersection of those biomes (e.g., subterranean below shoreline).

14 Indicators and combined presentations

14.1 Introduction

14.1 Indicators are used to summarize data and convey trends on topics of specific policy relevance. Examples of indicators include gross domestic product, the human development index and water use. Indicators provide the most common entry point to accounting data since they summarize the detail that is present in accounts. There is a large and increasing demand for indicators on environmental and sustainability related topics. In response, there is a wide array of indicators that have been, in most cases, not based on data that has been filtered through an accounting framework. In turn, this has led to challenges in comparability and consistency that affect the potential for indicators to be regularly incorporated into decision making processes. Indeed, an indicator can only be as robust as its underlying data. Since a feature of accounting frameworks is their organisation of data from multiple sources, there is potential for the SEEA EA to support the derivation of more coherent and consistent indicators.

14.2 In addition, given the variety of analytical and policy contexts that are present around the world, it is to be expected that people will consider combining accounts in different ways, or more commonly, focus on combining a subset of accounts that are most relevant for their specific needs. This is perfectly appropriate and should not be seen as suggesting that other combinations of accounting information for different applications or policy framings are inferior or irrelevant. In all cases, there is a need to ensure fitness for purpose both in terms of the accounting integration and the quality of the data required. Further, the development of indicators is commonly a dynamic process involving multiple stakeholders and responding to emerging policy issues. In that context, the discussion in these sections must be considered to be subject to ongoing evolution both as indicator processes evolve and as measurement of ecosystem accounts advances.

14.3 This chapter describes a range of ways in which data from the ecosystem accounts can be used to derive indicators and combined with other environmental-economic accounting and national accounting data to demonstrate the links between the economy and the environment and to compare trends over time. Section 14.2 summarises the roles and functions of SEEA EA based indicators and gives examples of these indicators. Section 14.3 explains links to reporting on progress towards various global environmental goals. Section 14.4 provides a general introduction to the development of combined presentations in which data from different accounts are presented alongside each other. These presentations may be particularly relevant in the derivation of indicators.

14.4 The discussion on indicators and combined presentations in this chapter complements the discussion in the SEEA Central Framework, chapter 6, that summarises a range of approaches to integrating and presenting accounting data. Additional inspiration for the types of indicators and analysis that can be supported by accounts is contained in SEEA Applications and Extensions (United Nations et al., 2017).

14.2 Indicators derived from the SEEA EA

14.2.1 Introduction

14.5 A clear understanding of the environment-economy nexus is critical in responding to a wide range of policy questions, often with regard to informing synergies and trade-offs in policy formulation. At a global policy level, relevant initiatives include the 2030 Agenda for Sustainable Development, the Post-2020 Global Biodiversity Framework, the Paris Agreement on climate change and the Convention to Combat Desertification (UNCCD). Further, current policy questions require an understanding of the relationship between the environment and economy that goes beyond information on individual environmental assets (e.g., timber, energy etc.). Increasingly, policy makers are defining sustainability in ways that also incorporate ecosystems and the services they provide to humanity.

14.6 These sub-sections describe how information from ecosystem accounts can be organized and integrated to provide policy-relevant indicators and aggregates. Initial discussion is on the roles and functions of indicators with respect to accounting frameworks before providing examples of indicators from the SEEA EA.

14.2.2 Roles and functions of SEEA EA indicators

14.7 An indicator is the representation of data for a specified time, place or any other relevant characteristic, corrected for at least one dimension (usually size) so as to allow for meaningful comparisons. It is a summary measure related to a key issue or phenomenon and derived from a series of observed facts.

14.8 Three main types of indicators are considered:

- Aggregates are statistics that are grouped together or aggregated in order to provide a broader picture. Thus, an aggregate is the combination of related categories, usually within a common branch of a hierarchy, to provide information at a broader level to that at which detailed observations are taken. In accounting, the aggregation is usually completed by simple addition, for example by summing the areas of ecosystem types across an ecosystem accounting area.
- Composite indices are those in which different variables are combined using a weighting pattern or aggregation rule to communicate the overall movement or trend. In the SEEA EA, an example of a composite index are measures of ecosystem condition which involve weighting together relevant ecosystem condition indicators.
- Ratio indicators are derived by combining data from different accounts, for example the flows of ecosystem services per hectare from different ecosystem types.

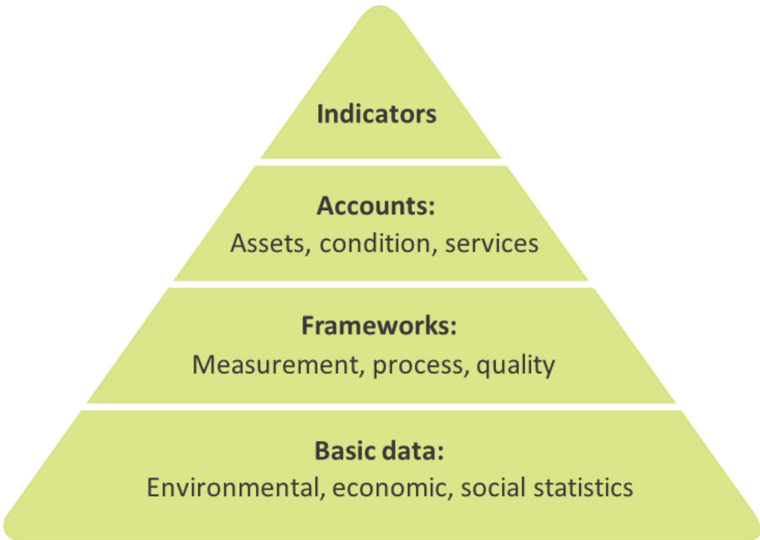
14.9 Indicators can be used to reveal relative positions or show positive or negative change over a regular interval. Indicators are usually a direct input into national and global policies. In strategic policy fields, they are important for setting targets and monitoring their achievement. By themselves, indicators do not necessarily contain all aspects of development or change, but they greatly contribute to explaining them. If consistent methodology is employed, they allow comparisons over time and between, for instance, countries and regions, and in this way assist in gathering 'evidence' for decision making. Indicators can also be used to aggregate fine-level geospatial data to show trends at sub-national or national scale.

14.10 Indicators can serve many purposes, depending on the scale at which they are applied, the target audience, and the quality of the underlying data. Indicators derived from the SEEA EA are useful tools for tracking progress with regards to ecosystems and biodiversity and for mainstreaming these issues into public policy. In doing so, these indicators can help promote the sustainable use of ecosystems and ecosystem services. More broadly, indicators can play an important role in supporting the communication of narratives about the environment and the connection to the economy and people.

14.11 The target audience of SEEA EA indicators usually comprise decision and policy makers in business and government, non-governmental organizations, environmental economists, ecologists, academia and the general public. The benefit of deriving indicators from the SEEA EA is that they are consistent, coherent, and accurately synthesize the underlying data, and are also understandable and meaningful to non-statisticians. SEEA EA indicators can therefore be statistically accurate as well as being straightforward and user-friendly. Indicators derived from the SEEA EA should therefore be seen as summary measures which are fit-for-purpose and are embedded within larger information systems (e.g., accounting frameworks, databases, monitoring systems and models) following consistent methodologies and workflows.

14.12 The relationship between different types of information within the context of the SEEA EA is shown in Figure 14.1. The base of the pyramid comprises a full range of basic statistics and data from various sources including from surveys, scientific measurements, geospatial data, administrative entities and censuses. Generally, these data are collected for several purposes and utilize different scopes, frequencies, definitions and classifications.

Figure 14.1: Information pyramid



Source: United Nations et al. (2017), Figure 2.1.

14.13 The role of the SEEA EA is to integrate those data to provide a coherent and unified understanding of ecosystems and their relationship to the economy. This means that compilers of SEEA EA accounts must reconcile and merge data from disparate sources, taking into account differences in scope, frequency, definition and classification, as appropriate. Once the data have been integrated within a single framework, indicators can be derived that provide insights into the changes in composition or structure of the specific concept of interest, changes in relationships between ecosystem stocks and flows, and other features, taking advantage of underlying relationships between the accounts.

14.14 Just as a myriad of indicators such as GDP, national saving and national wealth emerge from a single national accounts framework, so too can a wide range of indicators be derived from the SEEA EA. Moreover, the use of an accounting framework such as the SEEA EA provides significant benefits to the resulting indicators. These benefits include:

- Providing a stable conceptual framework that allows for new indicators to be developed from a coherent source to respond to new policy demands while also allowing for improvements in data collection and methods.

- Providing a broad framework such that different indicators can be seen in context and, as necessary, summary information conveyed in the indicator can be disaggregated to better understand the reasons for change.
- Allowing analysis, including forecasting and projections to build from the same coherent source data as the indicators.
- Support the derivation of early estimates using various assumptions based on benchmark data from the accounting system.

14.15 While indicators can be sourced directly from basic statistics, using an accounting framework necessitates reconciling and harmonizing the underlying data, which results in coherent and consistent indicators. This has the potential to better clarify the demand and priority needs for data – which can better link policy needs to data generation – and thereby to decision structure. Further, the alignment of the SEEA EA with the SNA facilitates a consistency between economic and environmental information which ensures the wider relevance of the indicators sourced from accounts.

14.2.3 Indicators from the ecosystem accounts

14.16 Information from ecosystem accounts can be organized and integrated to provide policy-relevant indicators. This section provides an overview of indicators that can be derived from the ecosystem accounts.

14.17 The majority of indicators presented in this section are output indicators that can be directly generated from the SEEA EA accounts for tracking national and global progress. They also contain indicators that have been developed and implemented by the scientific community, but nevertheless can be derived from the ecosystem or thematic accounts using additional compilation and analysis.

14.18 Considering the underpinning spatial framework of the SEEA EA and its integration with the SNA, indicators from each ecosystem account have the potential to crosswalk with data from other accounts and socio-economic measures. This can then provide integrated measures on the inter-connectiveness and linkage for a range of topics, such as adjusted macro-economic measures, costs of restoration, ecosystem capacity, etc. Indicators from the SEEA EA could also be designed to address distributional and environmental justice issues, for example, through aggregation and disaggregation to administrative units.

14.19 <u>Indicators from ecosystem extent accounts.</u> The ecosystem extent account describes the extent of the various ecosystem types presented in an accounting area and how the extent changes within the accounting period. The ecosystem types are based on the IUCN GET, which provides a top level of 4 realms, a 2nd level of 24 biomes and a 3rd level of 98 ecosystem functional groups. Depending on the application, alternative aggregations may be developed to align with the reporting requirements at the national and international level. In other contexts, it will be necessary to provide detail below the IUCN GET level to identify compositional differences at finer scales, for example within urban areas, that may affect the interpretation of aggregate level data.

14.20 Table 14.1 provides a selection of potential indicators that may be derived from the ecosystem extent account. Another possibility is to include measures of changes in the area of natural ecosystems compared to changes in anthropogenic and semi-natural ecosystems. Derivation of this indicator requires further definition of natural and semi-natural ecosystems in the context of the IUCN GET (or other classification of ecosystem types). It is also possible to establish a reference extent that reflects the composition of ecosystem types in a country at a given point in time and thus provides a common baseline for the assessment of change.

Table 14.1: Potential indicators on ecosystem extent

Extent indicators	Spatial unit	Disaggregation	Unit of measurement
Ecosystem accounting area covered by specific types or areas of interst, including: urban areas (IUCN GET T7.4) cultivated areas (IUCN GET T7.1, T7.2, T7.3) forests (IUCN GET T1, T2) wetlands (IUCN GET F1, F2, TF1, FM1, MFT1) coastal areas (IUCN GET M1, MT1, MT2, MT3, MFT1)	Ecosystem accounting area	Ecosystem type	Hectares; % of total EAA; % of opening
Change of area covered by specific ecosystem types or areas of interest during an accounting period, including: urban areas (IUCN GET T7.4) cultivated areas (IUCN GET T7.1, T7.2, T7.3) forests (IUCN GET T1, T2) wetlands (IUCN GET F1, F2, TF1, FM1, MFT1) coastal areas (IUCN GET M1, MT1, MT2, MT3, MFT1)	Ecosystem accounting area	Ecosystem type	% of opening
Percentage of area unchanged (opening stock – reduction)	Ecosystem accounting area	Ecosystem type	% of opening

14.21 Indicators from ecosystem condition accounts. The ecosystem condition account records data on the state and functioning of ecosystem assets within an ecosystem accounting area using a combination of relevant variables and indicators. The selected variables and indicators reflect changes over time in the key characteristics of each ecosystem asset. Ecosystem condition accounts are compiled in physical terms. Ecosystem condition indexes and sub-indexes (as shown in Table 14.2) are composite indicators that are aggregated from ecosystem condition indicators. The use of compatible reference levels (e.g., through a common reference condition) underpins the aggregation process. Many condition indicators that are developed and implemented by scientific communities can be integrated into the condition accounts of the SEEA EA for further aggregation.

Table 14.2: Potential indicators on ecosystem condition

Ecosystem condition indicators	Further description	Spatial unit	Disaggregation	Unit of measurement
Overall ecosystem condition index		Ecosystem accounting area	Ecosystem type, ecosystem condition classes	Index
Physical state indicator	Overall physical state characteristics of an ecosystem asset (including characteristics on soil structure, water availability, ocean temperature)	Ecosystem type	Ecosystem condition sub-classes	Index
Chemical state indicator	Overall chemical state characteristics of an ecosystem asset (including characteristics on soil nutrient levels, water quality, biogeochemistry, air pollutant concentrations)	Ecosystem type	Ecosystem condition sub-classes	Index
Compositional state indicator	Overall compositional state characteristics of an ecosystem asset (including characteristics on species diversity)	Ecosystem type	Ecosystem condition sub-classes	Index
Structural state indicator	Overall structural state characteristics of an ecosystem asset (including characteristics on vegetation (and biotic structure), biomass, food chains)	Ecosystem type	Ecosystem condition sub-classes	Index
Functional state indicator	Overall functional state characteristics on an ecosystem asset (including characteristics on ecosystem process, disturbances regimes)	Ecosystem type	Ecosystem condition sub-classes	Index
Landscape / seascape indicator	Overall characteristics on landscape/seascape (including landscape diversity, connectivity fragmentation, embedded semi-natural elements in farmland, coastal engineering)	Ecosystem type	Ecosystem condition sub-classes	Index

14.22 Indicators from the physical ecosystem services flow account. The physical ecosystem services flow accounts describe the ecosystem services generated by ecosystem asset in volume terms. The ecosystem services are grouped as provisioning, regulating and maintenance, and cultural services. Indicators from the accounts, such as those shown in Table 14.3, commonly focus on the ecological supply side of ecosystem service flows in physical units such as cubic metres and tonnes, but indicators linked to ecosystem contributions for human benefit can also take place through a focus on the use of ecosystem services. Where measures of ecosystem services are available by detailed type of use, for example by level of household income, it will be possible to consider the relative dependence of different groups of people on ecosystem services. Many of these indicators may also be expressed in monetary terms where valuation is also undertaken or linked to other related economic data, such as concerning the value added and employment of relevant industries.

Table 14.3: Potential indicators on physical ecosystem services flows

Physical ecosystem services flow indicators	Further description	Spatial unit	Disaggregation	Unit of measurement
Amount of biomass harvested including crops, grazed biomass, livestock, wood, non-wood forest products, fish, and others.	Biomass provisioning services	Ecosystem accounting area	Ecosystem type; Type of biomass	Tonnes
Water abstracted for use by household and industry (proxy measure)	Water supply services	Ecosystem accounting area	Ecosystem type	Cubic metres
Quantity of carbon retained (captured and stored/trend in the carbon sequestered)	Global climate regulation services	Ecosystem accounting area	Ecosystem type	Tonnes
Quantity of airborne pollutants captured (e.g., PM10; PM2.5)	Air filtration services	Ecosystem accounting area	Ecosystem type; type of pollutant	Tonnes
Quantity of waterborne pollutants removed (e.g., chemical oxygen demand) from wastewater	Water purification services	Ecosystem accounting area	Ecosystem type, type of pollutant	Tonnes
Number of properties/ km of coast/shoreline/riparian zone protected; change in degree of risk	Flood mitigation services	Ecosystem accounting area	Ecosystem type	Count/km
Number of tourist/recreation visits	Recreation-related services	Ecosystem accounting area	Ecosystem type	Count

14.23 Indicators from the monetary ecosystem services flow account and ecosystem asset account. The monetary ecosystem services flow accounts describe the ecosystem services generated by the ecosystem asset in monetary terms. The monetary ecosystem asset account describes the opening and closing exchange value of ecosystem assets over an accounting based on the net present value of the bundles of ecosystem services, under their current use/institutional regime. When compiled for multiple years, the asset account records the cost of degradation and /or enhancement (e.g., restoration) of ecosystem assets that can be identified by exchange value.

14.24 Many SEEA EA indicators in monetary terms are aggregates derived from adding and subtracting relevant entries in individual monetary accounts such as the ecosystem services flow account and the monetary ecosystem asset account. Aggregates can be defined in different ways by determining different inclusions and exclusions. Other monetary indicators can be derived by comparing aggregates with other economic data such as the total value of other assets, expected ecosystem restoration costs, or the value added of industries dependent on ecosystem services or at risk if ecosystem services are lost.

14.25 Finally, because the data on different ecosystem services and ecosystem types are expressed using a common metric (i.e., currency units), comparisons and ratios can be estimated for example showing the relative shares of provisioning, regulating and maintenance and cultural services. Table 14.4 includes a sub-set of possible monetary aggregates and other indicators. It will be relevant to analyse indicators in monetary terms in combination with data in physical terms, for example in relation to flows of ecosystem services in physical terms or in relation to the extent and condition of different ecosystem types.

Table 14.4: Potential indicators on monetary ecosystem services flows account and ecosystem asset accounts

Monetary indicators	Further description	Spatial unit	Disaggregation	Unit of measurement
Gross Ecosystem Product (GEP)	GEP is equal to the sum of all final ecosystem services at their exchange value supplied by all ecosystem types located within an ecosystem accounting area over an accounting period less the net imports of intermediate services (for additional notes see para. 9.18).	Ecosystem accounting area	Ecosystem type, ecosystem services classes	Local currency
Industry value added linked to ecosystem services	Value added of industries with direct inputs of ecosystem services reflecting extent to which economic activities are dependent on ecosystem services.	Ecosystem accounting area	Ecosystem type	Local currency
Monetary ecosystem asset value	End of year monetary ecosystem asset value	Ecosystem accounting area	Ecosystem type	Local currency
Cost of degradation	Reduction to addition of monetary ecosystem asset value attributable to ecosystem degradation	Ecosystem accounting area	Ecosystem type, per capita by administrative areas, planning areas	Local currency

14.2.4 Indicators from thematic accounts

14.26 Chapter 13 introduces a range of thematic accounts covering biodiversity, climate change, oceans and urban areas. In each of these themes, various data are brought together under an accounting umbrella and demonstrate the potential for the suite of SEEA accounts, including those of the SEEA Central Framework, to provide a broad range of data which, together with data from other sources including the SNA, can support discussion of these and other themes. Indicators for each theme can be derived based on the considerations outlined in this chapter.

14.3 Indicator frameworks and the SEEA EA

14.3.1 SEEA EA and global indicator monitoring frameworks

14.27 The SEEA enables countries to adopt a holistic and integrated approach to developing sets of indicators to support the implementation, monitoring and reporting of sustainable development agenda and the post-2020 global biodiversity framework. The United Nations Statistical Commission at its 51st Session in March 2020 "*welcomed the background document on interlinkages …… and stressed the importance of the System of Environmental Economic*

Accounting for monitoring the Goals".[161] At its 52nd Session in March 2021, UNSC "welcomed the progress of the Committee in mainstreaming the use of the SEEA in policy, including climate change, circular economy, sustainable finance, and biodiversity policy, and particularly encouraged the Committee to engage in the monitoring framework of the post-2020 global biodiversity agenda and participate in the proposed expert group under the auspices of the Secretariat of the CBD to provide the connection between the biodiversity and official statistical communities".[162]

14.28 The SEEA provides two general advantages in relation to indicator monitoring frameworks. First, the SEEA's broad coverage of environmental and economic topics, inherent connections between stocks and flows and the use of physical and monetary data, enables those designing and selecting indicators to place different indicators in context. Thus, the SEEA can allow connections between indicators to be made evident in the development of monitoring frameworks and can be used to support appropriate coverage of indicators across relevant themes. Second, the SEEA enables countries to use a single, coherent database for reporting to multiple monitoring frameworks. This has the potential to streamline data collection and organisation and build more robust, consistent indicator derivation across reporting commitments.

14.29 In discussing the potential of the SEEA to support the design and derivation of indicators in different contexts, it must be understood that monitoring frameworks will continue to evolve in response to emerging policy demands and reflecting wider engagement processes. The discussion here therefore points to the potential relationships and application of the SEEA. Specific guidance on the links between the SEEA and individual monitoring frameworks will be developed progressively.

14.30 Post-2020 Global Biodiversity Framework. The post-2020 global biodiversity framework builds on the Strategic Plan for Biodiversity 2011-2020 and sets out an ambitious plan to implement broad-based action to bring about a transformation in society's relationship with biodiversity and to ensure that, by 2050, the shared vision of living in harmony with nature is fulfilled. The framework has four long-term goals for 2050 related to the 2050 Vision for Biodiversity. Each of these goals has an associated outcome for 2030. The framework also has 21 action-oriented targets for 2030 which will contribute to the outcome-oriented goals for 2030 and 2050. Under each goal and target, there are a set of components and monitoring elements to be monitored in assessing progress towards them.

14.31 The SEEA can support the post-2020 global biodiversity framework where it concerns measuring ecosystems' extent, condition and services while also helping make the case for protecting and conserving biodiversity by providing a full picture of its connection to the economy. In particular, the information generated by the SEEA can be used to inform biodiversity policies in an integrated and holistic manner and develop indicators for monitoring progress toward the achievement of biodiversity goals and targets. As described in section 13.3, this can include the use of data from ecosystem extent and condition accounts as inputs to deriving habitat-based indicators of change in species-level biodiversity. The SEEA can also play an important role in streamlining the reporting requirements of countries through the adoption of a common framework. This can, in turn, also facilitate better integration between national and global target tracking.

---

[161] United Nations Statistical Commission, Report on the fifty-first session, E/2020/24, para (g), https://undocs.org/E/2020/24.

[162] United Nations Statistical Commission, Report on the fifty-second session, E/2021/24, decision 8g, https://unstats.un.org/unsd/statcom/52nd-session/documents/2021-30-FinalReport-E.pdf.

14.32 Annex 14.1 presents the 2050 Goals and 2030 Targets of the Post-2020 Global Biodiversity Framework that can be informed using SEEA based accounts.

14.33 Sustainable Development Goals. The 2030 Agenda for Sustainable Development was adopted by all United Nations Member States in 2015. It is built around 17 SDGs and 169 targets that represent an ambitious plan for achieving sustainable development and serves as the basis for countries to shape their national policies and priorities. At the heart of the agenda is the recognition that true development must combine economic growth and poverty alleviation with strategies that improve health and education, and reduce inequality, while also addressing climate change and protecting nature. Thus, the interlinked nature of the SDGs calls for an integrated approach to policy decisions. As the international statistical standard for measuring the environment and its relationship with the economy, the SEEA is well positioned to support integrated policies based on a better understanding of the interactions, trade-offs and co-benefits that arise in evaluating the link between the environment and economy.

14.3.2 Other indicators and applications

14.34 National indicator initiatives. In addition to supporting global indicator initiatives, the SEEA EA also enables countries to adopt a holistic and integrated approach to develop sets of indicators to support reporting on progress towards national commitments, policies or strategy. The spatially explicit information generated using the SEEA EA enables the effective targeting of policy efforts at both national and sub-national levels and across terrestrial, freshwaters and marine areas. The modular and flexible approach allows countries to compile SEEA EA indicators based on national priorities and data availability.

14.35 The connectivity and coherence of information sourced from the accounts of the SEEA EA Framework and its flexible approach are particularly important when the indicators are designed to support national policies related to sustainable development and conservation of ecosystems and biodiversity.

14.36 National indicators that benefit most from having their foundation in the SEEA EA include those related to:

- Contribution of ecosystems and their services to the economy, social wellbeing, jobs and livelihoods;
- Changes in the condition and health of ecosystems and biodiversity over time and the main locations of degradation and enhancement;
- Management of natural resources and ecosystems to ensure continued services and benefits such as energy, food supply, water supply, flood control, carbon storage and recreation opportunity;
- Progress towards targeted conservation efforts;
- Expenditures and the development of economic instruments on nature conservation;
- Estimation of a nation’s wealth including natural capital and economic potential once the state of nature is considered;
- Assessment of government performance on sustainable development.

14.37 The design and implementation of SEEA EA indicators to support national policy requires strategic planning and the establishment of appropriate institutional mechanisms and arrangements for the ongoing compilation of accounts and subsequent calculation of indicators. Ultimately, the implementation of the SEEA EA should support a coordinated, long term, national programme of work involving a range of users of the accounts and a number of different source data agencies. The national statistical office has a fundamental role in coordinating this process.

14.38 Land Degradation Neutrality. The structure of the SEEA EA, with its emphasis of spatial analysis of ecosystems in terms of their extent, condition and ecosystem services, corresponds well to the data needs for monitoring land degradation neutrality (LDN). The three global LDN indicators (land cover, land productivity, and carbon stocks) that are used to derive SDG Indicator 15.3.1 — Proportion of land that is degraded over total land area — can all be derived from existing core SEEA accounts:

- SEEA land accounts present detailed spatial data on land cover;
- SEEA ecosystem condition accounts measure the overall quality of an ecosystem asset with a range of variables including soil organic carbon (SOC), annual net primary productivity and changes in above and below ground carbon stores; and
- SEEA ecosystem services accounts measure the global climate regulation services provided by the ecosystem.

14.39 The UNCCD encourages countries to supplement their monitoring with additional indicators for ecosystem services and social outcomes that address their national or sub-national priorities. The SEEA's alignment with the SNA means that data organized under the framework can be integrated and used with existing economic accounts relatively easily. As the principle of neutrality will usually involve offsetting degradation in some areas with improvements in others, the SEEA's comprehensive framework provides information for helping identify key trade-offs and the spatial targeting of restoration efforts.

14.40 Intergovernmental Science policy Platform on Biodiversity and Ecosystem Services (IPBES). The overall objective of the IPBES is to provide policy relevant knowledge on biodiversity and ecosystem services to inform decision making, with four agreed functions on assessment, policy support tools development, capacity building and knowledge development. A conceptual framework has been developed to support the analytical work of the Platform, to guide the development, implementation and evolution of its work programme, and to catalyse a positive transformation in the elements and interlinkages that are the causes of detrimental changes in biodiversity and ecosystems and subsequent loss of their benefits to present and future generations. The conceptual framework includes six interlinked elements constituting a social-ecological system that operates at various scales in time and space. The ecosystem accounting framework of the SEEA EA captures many of the elements of the IPBES framework and hence there is the potential for SEEA EA based indicators to inform IPBES assessments and related work.

14.41 RAMSAR Convention on Wetlands. The Ramsar COP in 2005 agreed on an initial set of eight ecological outcome-oriented indicators, for assessing the effectiveness of aspects of the Convention's implementation. These eight indicators were available during the 2006-2008 triennium - they covered wetland resource status and threats, Ramsar site status and threats, water resources status, wetland management, species/population status, threatened species and Ramsar Site designation progress. An additional two sub-indicators were developed to further examine the status of wetlands - status and trends in ecosystem extent, and trends in conservation status.

14.42 Across the four strategic goals of the Ramsar convention a total of 19 targets are specified in the strategic plan. In order to track progress towards the Strategic Targets of the convention, a series of indicator questions are posed to countries in section 3 of the national report template for the Ramsar Convention, which should be completed for each conference of contracting parties. A number of indicators were identified as being able to be supported by SEEA based accounts:

- Change in the extent of wetland ecosystems
- Trend in wetland condition
- Number of households linked to sewage system
- Percentage of sewage coverage in the country
- Number of wastewater treatment plants

14.43 The Group on Earth Observations – Biodiversity Observation Network (GEO BON). GEO BON is a global network working to improve the acquisition, coordination and delivery of biodiversity observations for decision-making. As a network representing key biodiversity data providers operating at local, national, regional and global scales and through its efforts to design and implement structured and interoperable, national biodiversity observation networks, the GEO BON network has direct utility to the implementation of the SEEA EA process as a whole and in particular with regard to the production of natural capital accounts and related indicators.

14.44 Of particular relevance is the establishment of a scalable and interoperable framework for biodiversity observations, using the concept of Essential Biodiversity Variables (EBVs). The EBVs cover the key dimensions of biodiversity spanning six classes (Species Populations, Species Traits, Genetic Composition, Community Composition, Ecosystem Structure, and Ecosystem Function). EBVs optimize the use of in-situ and remote sensing data, predictive models and repeated measures at the same locations for trend detection and attributions of ecosystems change. In addition, a new framework is being developed for Essential Ecosystem Services Variables (EESVs) that provides a flexible means for measuring change in a wide range of material, non-material and cultural services that biodiversity and ecosystems provide. The interactions and dynamics within and across biodiversity, ecosystem functions and ecosystem services - ecological feedbacks as well as socio-ecological feedbacks - can be assessed using relevant sets of EBVs and EESVs.

14.45 The EBVs and EESVs are being implemented via structured and repeatable workflows that can be applied at multiple scales that connect primary observation data to multiple biodiversity information products. These workflows are being utilized to develop a new suite of time-series indicators for tracking the status and trends in key dimensions of biodiversity change and patterns. Therefore, both the EBVs themselves and their integrated outputs (e.g., indicators) are of direct relevance to many of the indicators for the SEEA EA indicators initiative. Through the SEEA EA framework, which supports open, standardised and interoperable indicator development, EBVs and EESVs can also provide underlying data products to inform a wide range of policy frameworks, including the CBD, SDGs and Multilateral Environmental Agreements (MEAs). Continuous interactions and exchange between biodiversity data developers and national to global statistics authorities will be instrumental in generating demand driven, science-based, and timely SEEA EA indicators in a coherent and consistent manner across scale and sectors. Kim et al. (n.d.) provide a detailed assessment of the potential connections between the SEEA EA and GEO BON.

14.46 The Global Ocean Observing System of IOC-UNESCO (GOOS). GOOS was established in 1991 by member states of the Intergovernmental Oceanographic Commission with the World Meteorological Organisation, UN Environment and subsequently the International Science Council. The GOOS community and its partners have coordinated global ocean climate observing and information products and over the last decade is developing an integrated global observing system including biology, ecosystems and ocean health.

14.47 GOOS has the responsibility to develop and extend the Essential Ocean Variables (EOVs) and the marine Essential Climate Variables (ECVs). The physical and biogeochemical EOVs measure the physical and chemical condition of marine ecosystems and will support potential indicators on the condition of marine and coastal ecosystems following Table 14.2. Biological EOVs measure the extent and condition of marine ecosystems of particular relevance to countries reporting to global environmental conventions. Both EOVs and ECVs can align to classifications under the IUCN GET. They support global carbon modelling, investments in blue carbon, and selection of natural ecosystems for headline indicators of the post-2020 GBF. They can also serve as potential indicators on ecosystem extent and condition and flows for the SEEA EA (Tables 14.1, 14.2 and 14.3). GOOS works closely with the Marine Biodiversity Observation Network (MBON) of GEOBON as the biological EOVs provide the underlying data from which marine EBVs will be computed.

14.48 Biodiversity Finance Initiative (BIOFIN). BIOFIN provides an innovative approach enabling countries to measure their current biodiversity expenditures, assess their financial needs in the medium term and identify the most suitable finance solutions to bridge their national biodiversity finance gaps. BIOFIN is currently active in 30 countries and has produced intermediate guidance on the categorization of biodiversity expenditures based on nine categories.

14.49 Work is underway to harmonize the classification system for biodiversity expenditures between BIOFIN, the Environmental Expenditure Accounts of the SEEA Central Framework and the SDG indicators related to expenditure on conservation and sustainable use of biodiversity and ecosystems.

14.50 Inclusive Wealth. The Inclusive Wealth Index is a sustainability index that measures wealth using countries' natural, manufactured, human and social capital. These can be used to complement existing national accounts including measures of GDP. The Inclusive Wealth Index incorporates natural capital, human capital (e.g., education and wealth) and produced capital (e.g., equipment, machineries, roads) - while also recognising changing factors such as carbon damage, oil capital gains and total factor productivity. These factors are measured within countries, and therefore show rates at national levels. The monetary value of ecosystem assets derived from the monetary ecosystem asset account of the SEEA EA can support measures of the natural capital component of Inclusive Wealth, recognising that monetary values based on shadow prices may be appropriate depending on the analytical context (see chapter 12).

14.51 Biophysical modelling. Modelling for SEEA EA is important as there are several challenges in assembling ecosystem accounts to derive indicators. First, the data needed to assemble ecosystem accounts are not typically captured in data sources that statistical offices rely on, such as surveys, administrative data, and censuses. The second challenge is that the SEEA EA is a spatially explicit framework, which ultimately requires mapping of both ecosystems and ecosystem services. Consequently, even measurements of ecosystem services that are regularly collected through household or agricultural surveys need to be spatially explicit. Finally, reporting environmental data in a way that can be integrated into accounting frameworks without oversimplifying complex ecological and socioeconomic processes underpinning ecosystem services is challenging. SEEA EA is an attempt to merge disciplinary perspectives from ecology, economics, and accounting by providing a spatially explicit accounting framework for ecosystem services, while also avoiding double counting of the economic contributions of ecosystem benefits.

14.52 Biophysical modelling can fill gaps where information is not readily available, as well as spatially allocate data that is not regularly spatially explicit. Diverse models and tools to estimate the physical supply of ecosystem services have proliferated over the past decade and are quickly evolving, which means compilation of ecosystem accounts by statistical agencies is increasingly feasible. While most biophysical models were not developed specifically for accounting, many models produce results that can be used directly in SEEA EA or produce results that can be modified for use in SEEA EA. Identifying which tools and modelling platforms produce results that align with SEEA EA can facilitate faster adoption of ecosystem accounts.

14.53 Scenario analysis. SEEA EA can be deployed in the application of scenario analysis to support policymaking. The increasing interconnectedness between the natural environment, human societies and their economies implies new challenges and opportunities for policymakers. To adequately take account of such complexities, policymakers require new sources of data and indicators, based on coherent statistical frameworks, that can be transformed into decision-relevant information through the application of innovative, sophisticated modelling techniques. The Technical report on policy scenario analysis using SEEA ecosystem accounts (UNEP & UNSD, n.d., forthcoming) and the IPBES report on scenario analysis (Ferrier et al., 2016) are sources of further detail in this area of work.

14.54 The creation and quantification of scenarios with mathematical simulation models allows for the creation of quantitative estimates for various scenarios (e.g., of implementing or not implementing a proposed policy) that can be used to inform the policymaking process. This is policy scenario analysis i.e., an exercise that aims at informing decision making and makes use of scenarios to assess the outcomes and effectiveness of various policy intervention options.

14.55 The SEEA EA, by providing a standardized approach, consistent and coherent data, and, by targeting policy relevance and the involvement of local stakeholders in policy analysis, can both support the use of accounts, further development of modelling approaches and creation of new models, all with the ultimate goal of informing policy decisions. This can happen through:

- Creation of new knowledge about ecosystems and how their extent and quality leads to ecosystem services that benefit communities and human wellbeing. This allows for the incorporation of ecosystems in social and economic assessments.
- Creation of coherent and harmonized accounts, allowing for the development of new models that can make use of such a data framework.
- Promotion of the use of a systemic approach that assesses (i) the impact of human activity on ecosystems and (ii) models that determine the extent to which ecosystems influence human health and human activity.
- Application of standard approaches to valuation of ecosystem services and ecosystem assets based on exchange values.
- Improving the analysis performed with sectoral models, by introducing physical indicators on ecosystem extent, condition, services.
- Generating knowledge on how existing models could be connected with one another to better represent the relations between society, economy and environment.
- Use of simulations, extending the analysis provided by SEEA, by forecasting or back-casting scenarios.
- Making explicit the importance of site-specific drivers of change, system responses and impacts, with the use of a spatially-explicit analysis that allows users to determine the value of ecosystem services based on the location they are used (i.e., more explicitly assess demand and supply).

14.4 Combined presentations for ecosystem accounting

14.4.1 Introduction

14.56 The presentation of data in a format that combines both physical and monetary data is one of the strongest features of the SEEA. The SEEA Central Framework, chapter 6, introduces combined presentations as a way of summarizing the data from various accounts and linking to other relevant data, for example on population or employment. In the context of the SEEA EA, combined presentations are intended to show changes in stocks and flows of ecosystems in the context of standard measures of economic activity, without necessarily undertaking the valuation of ecosystem services and ecosystem assets in monetary terms. There is room for considerable flexibility in the design of combined presentations. The following sub-sections describe common areas of interest rather than an exhaustive list.

14.57 While they do not encompass a full integration of information in accounting terms, combined presentations can support a more informed discussion of the relationship between ecosystems and economic activity in a manner that takes into account spatial and environmental contexts. Further, they may help support the presentation of indicators for monitoring trends in ecosystem-related outcomes.

14.58 In selecting the relevant variables to include in a combined presentation, it is necessary to have in mind a specific question or focus of analysis such that the selected variables can be shown to be contributing to a broader narrative and hence contextualizing the variables. For this purpose, it may be relevant to apply indicator frameworks such as the long-standing driving force, pressure, state, impact, response (DPSIR) framework (European Environment Agency, 1999) or more recently developed frameworks such as the environmental sustainability gap framework or the natural capital indictor framework. The links between the DPSIR framework and the SEEA are considered in this section as an example of the possibilities, following an introduction of specific topics that might be the focus of a combined presentation. Note that the SEEA does not advocate for any specific indicator framework.

14.4.2 Information on environmental activities

14.59 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 on relevant activities is organized to refer to the same spatial areas and/or ecosystem types, this would facilitate the monitoring of the effect of expenditures on changes in ecosystems.[163] For example, information may be combined showing expenditure to restore coastal wetlands with associated changes in ecosystem condition and associated ecosystem services linked to improved ecosystem condition.

14.60 As defined in the SEEA Central Framework,[164] environmental activities are economic activities that have a primary purpose of either environmental protection (the prevention, reduction and elimination of pollution and other forms of degradation); or resource management (preserving and maintaining the stock of natural resources).

14.61 Over time, information gathered on the actual expenditure on restoring ecosystem assets might be complemented by information on flows of ecosystem services, through which a more complete picture of the relationships between ecosystem condition and ecosystem services could emerge. Further, links may be made to analysis of positive and negative

[163] 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.
[164] For details see the SEEA Central Framework, chapter 4.

externalities, ecosystem disservices and the extent to which expenditures and other policy responses are reducing any negative effects. Indeed, one of the key roles of the ecosystem accounting model is to facilitate the organization of these types of data and thereby furnish support for more detailed analyses.

14.62 The compilation of targeted statistics on the production of ecosystem related environmental goods and services, using the framework of the environmental goods and services sector (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 related to ecosystems and biodiversity (sometimes called the biodiversity economy).

14.4.3 Economic dependence on ecosystems

14.63 Although the focus of ecosystem accounting is on the services provided by ecosystems, there is also interest in understanding the significance of the relationship between ecosystems and standard measures of economic activity, such as GDP. For example, it may be of interest to understand the dependency of current measures of agricultural production on ecosystem service such as pollination. Such dependency measures could be focused around the direct impact (e.g., GDP 'at risk' in the absence of the pollination service), but may also take indirect (or supply chain) effects into account by measuring multiplier effects within the economy, using the extended supply and use table described in chapter 11. In situations where the total contribution of ecosystem services (expressed as percentage of GDP) is low, it is possible that economic dependency could still be very high.

14.64 It should be accepted that the allocation of economic activity to sub-national spatial areas (such as administrative regions, or catchments) can be conceptually difficult. 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. Further economic connections may also be identified by tracing supply chains.

14.4.4 Information on policy instruments

14.65 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. From a general environmental management perspective, a comparison of environmental expenditures and environmentally related revenues may also be of interest.

14.4.5 Using the DPSIR framework

14.66 A number of indicators for the analysis of various topics can described using the Driving forces, Pressure, State, Impact and Response (DPSIR) framework (European Environment Agency, 1999), which describes a step-wise causal chain between economic activity and impacts on nature. Indicators that benefit most from having their foundation in the accounts of the SEEA

EA are mostly communicated as either the state or impact indicators in the DPSIR framework. By extending the scope of analysis and by integrating statistics and indicators from the SEEA Central Framework and other socio-economic dimensions with the SEEA EA, the SEEA lends itself to the derivation of a wide range of important indicators that are considered as policy relevant and that can also be communicated through the DPSIR framework.

14.67 *Driving force indicators:* Driving forces are anthropogenic activities that cause pressure on ecosystems. Indicators for driving forces describe the social, demographic and economic developments in societies and the corresponding changes in consumption and production patterns. Primary driving forces are population growth and developments in the demand and consumption/production activities by economic agent, which exert pressures on the ecosystem. Example of indicators on driving forces on ecosystem within the general context of SEEA are shown in Table 14.5.

Table 14.5: Possible SEEA based Driving force indicators

Type	Indicators	Spatial unit	Related SEEA accounts, and statistics from other dimensions
Combined presentation	Population per hectare of ecosystem type	Ecosystem type	Ecosystem extent account; Population statistics disaggregate by ecosystem type
Combined presentation	Resource intensity in an ecosystem accounting area (i.e., ratio of natural resources such as water use to an economic variable such as output, income and value added)	Ecosystem accounting area	Ecosystem extent account; SEEA CF physical flow accounts; economic statistics

14.68 *Pressure indicators:* Pressures are direct stresses from anthropogenic activities to ecosystems such as emissions to air, water and waste and the release of excessive nutrients. The pressures exerted by the driving forces are transformed in a variety of biophysical and ecological process to manifest them in changes in ecosystem conditions. Example of pressure indicators on ecosystem within the general context of SEEA are shown in Table 14.6.

Table 14.6: Possible SEEA based Pressure indicators

Type	Indicators	Spatial unit	Related SEEA accounts, and statistics from other dimensions
Combined presentation	Hazardous waste generated per industry sector	Ecosystem type	Ecosystem extent account; SEEA Solid waste accounts
Combined presentation	Greenhouse gas emission per industry sector	Ecosystem type	Ecosystem extent account; SEEA CF air emission account
Combined presentation	Water emission (BOD/COD, phosphorus, nitrogen, etc) per industry sector	Ecosystem type	Ecosystem extent account; SEEA CF water emission account

14.69 *State indicators:* State indicators give a description of the quantity and quality of physical, biological and chemical phenomena in a certain area. In the context of SEEA EA, they refer to the state of ecosystems in terms of its extent, condition and capacity to provide services to humanity and the conditions of the environment. Indicators derived from the ecosystem extent and condition accounts of the SEEA EA are considered state indicators.

14.70 *Impact indicators*: Changes in the state of environment due to natural changes, pressures on the environment or human intervention will have impacts on the social and economic functions on the environment. Impact indicators from the SEEA EA include measures of changes in ecosystems and human systems, such as the provision of ecosystem services and degradation of ecosystems. Indicators derived from the physical and monetary ecosystem services flow account as well as the monetary ecosystem asset account of the SEEA EA are considered impact indicators. Some examples are shown in Table 14.7. Other types of impact indicators within the general context of SEEA include:

- Indicators derived from Integrated and extended accounting (chapter 11 of the SEEA EA);
- Indicators derived from the combination of physical and monetary accounts;
- Indicators measuring economic dependence on ecosystems; and
- Indicators derived from analytical model using SEEA data for the analysis of consumption and production pattern, including, for example footprint-type indicators.

Table 14.7: Possible SEEA based Impact indicators

Type	Indicators	Spatial unit	Related SEEA accounts, and statistics from other dimensions
Integrated and extended accounting	Net domestic product adjusted for cost of degradation	Ecosystem accounting area	Extended sequence of accounts
Combined presentation	The area of ecosystem that has seen an increase in condition	Ecosystem type	Ecosystem extent account; Ecosystem condition account
Combined presentation	GEP per hectare of ecosystem type	Ecosystem type	Ecosystem extent account; Monetary ecosystem services flow account
Combined presentation	Ratio of ecosystem asset value to service value	Ecosystem type	Monetary ecosystem services flow account Monetary ecosystem asset account;
Economic dependence on ecosystem	Economic activity dependent on nature (e.g., Value of ecosystem services linked to industry value added)	Ecosystem accounting area	Monetary ecosystem services flows accounts; SNA; Industrial statistics
Environmental-extend Multi-regional input-output analysis	Ecosystem footprint (e.g., ecosystem service embodied in a country import and export of goods and services) (of which carbon and water footprints would be example)	Ecosystem accounting area	Monetary ecosystem services flow accounts; Input-output analysis

14.71 *Response indicators*: Responses are management actions to address environmental problems to prevent, compensate, ameliorate or adapt to changes in the state of the environment. Potential types of response indicators in the SEEA context cover the following areas with examples of possible response indicators from the SEEA shown in Table 14.8:

- Indicators on environmental activities and EGSS;

- Tax and expenditure indicators such as environmental protection and resource management expenditures and environmental taxes; and
- Indicators on policy instruments to safeguard ecosystem condition.

Table 14.8: Possible SEEA based driving force indicators

Type	Indicators	Spatial unit	Related SEEA accounts, and statistics from other dimensions
Environmental activities	Value added and employment generate by the environmental good and service sectors per ecosystem type	Ecosystem type	EGSS; SNA; economic statistics
Tax and expenditure	Return on biodiversity expenditure (change in ecosystem condition index per dollar spent)	Ecosystem accounting area	Ecosystem condition account; Environmental protection and expenditure account
Tax and expenditure	Biodiversity related environmental tax	Ecosystem accounting area	Accounting for environmental tax
Policy instrument	Integration of biodiversity into national accounting and reporting systems, defined as implementation of the SEEA		

Annex 14.1: SEEA EA and the post-2020 Global Biodiversity Framework[165]

A14.1 The role of the official statistical community and the value of SEEA in monitoring the post-2020 global biodiversity framework and mainstreaming biodiversity in the national statistical system are recognized at a political level. The 24th meeting of the Subsidiary Body on Scientific, Technical and Technological Advance (SBSTTA) of the Conference of the Parties (CoP) of the CBD reviewed documents *Post-2020 Global Biodiversity Framework: Scientific And Technical Information To Support The Review Of The Updated Goals And Targets, And Related Indicators And Baselines*[166] and *Proposed Indicators And Monitoring Approach For The Post-2020 Global Biodiversity Framework*,[167] which include a recommendation for the CoP at its 15th meeting to adopt a decision that:

- *Adopts* the monitoring framework for the post-2020 global biodiversity framework;
- *Welcomes* the work of the United Nations Statistics Division to develop statistical standards for measuring biodiversity, the environment and their relationship with socioeconomic development as well as their support to national statistical offices to engage in the process for monitoring biodiversity;
- *Invites* the United Nations Statistical Commission to support the operationalization of the monitoring framework for the post-2020 global biodiversity framework;
- *Recognizes* the value of aligning national monitoring with the United Nations System of Environmental-Economic Accounting statistical standard in order to mainstream biodiversity in national statistical systems and to strengthen national monitoring systems and reporting.

A14.2 A monitoring framework composed of three groups of indicators is proposed for monitoring the implementation of the post-2020 global biodiversity framework:

- *Group 1 - Headline indicators*: A minimum set of high-level indicators which capture the overall scope of the goals and targets of the post-2020 global biodiversity framework which can be used for tracking national progress, as well as for tracking regional and global progress. These indicators could also be used for communication purposes. Additionally, some countries may wish to use a subset of these indicators or only the goal-level headline indicators for high-level communication and outreach.
- *Group 2 - Component indicators:* A set of indicators for monitoring each component of each goal and target of the post-2020 Global Biodiversity Framework at the national level as well as for tracking regional and global progress.
- *Group 3 - Complementary indicators*: A set of indicators for thematic or in-depth analysis of each goal and target and which are less relevant for a majority of countries; have significant methodological or data collection gaps; are highly specific and do not cover the scope of a goal or target component; or can only be applied at the global and regional level.

[165] This annex is based on indicators in July 2021, which are still under consideration by the Conference of the Parties.

[166] Post-2020 Global Biodiversity Framework: Scientific and Technical Information to Support the Review of the Updated Goals and Targets, and Related Indicators and Baselines, CBD/SBSTTA/24/3. https://www.cbd.int/doc/c/705d/6b4b/a1a463c1b19392bde6fa08f3/sbstta-24-03-en.pdf

[167] Post-2020 Global Biodiversity Framework: Scientific and Technical Information to Support the Review of the Updated Goals and Targets, and Related Indicators and Baselines, Proposed Indicators and Monitoring Approach for the Post-2020 Global Biodiversity Framework, CBD/SBSTTA/24/3/Add.1. https://www.cbd.int/doc/c/ddf4/06ce/f004afa32d48740b6c21ab98/sbstta-24-03-add1-en.pdf

A14.3 Within these three groups, different types of indicators are proposed for the goals and targets of the post-2020 Global Biodiversity Framework. The indicators proposed for the goals focus on the status and trends in biodiversity, including the benefits biodiversity provides to people and the conditions necessary for achieving the framework. The indicators proposed for the targets aim to monitor the actions taken to reach the targets and their impacts.

A14.4 With regard to the selection of headline indicators priority has been given to indicators that have been agreed through an established scientific or intergovernmental process and where there is an existing body that will continue to review the indicator. An effort was made to align with the intergovernmental processes under the United Nations Statistical Commission, including the SDGs or the SEEA.[168]

A14.5 The discussion on the headline indicators for the post-2020 global biodiversity framework is ongoing. Below is a selected list of proposed headline indicators that can be derived from the SEEA accounts, noting that SEEA is recognized as the methodological basis for the headline indicators on at least 6 Goals and Targets (Goal A and B; Target 9, 11, 14 and 19) in the monitoring framework.[169]

- Extent of selected natural and modified ecosystem (i.e. forest, savannahs and grasslands, wetlands, mangroves, saltmarshes, coral reef, seagrass, macroalgae and intertidal habitats);
- National environmental economic accounts of ecosystem services ;
- National green-house gas inventories from land use and land use change;
- National environmental-economic accounts of benefits from the use of wild species;
- National environmental-economic accounts of regulation of air quality, quality and quantity of water, and protection from hazards and extreme events for all people, from ecosystems;
- Average share of the built-up area of cities that is green/blue space for public use for all;
- Integration of biodiversity into national accounting and reporting systems, defined as implementation of the System of Environmental-Economic Accounting;
- Material footprint per capital;
- Public expenditure and private expenditure on conservation and sustainable use of biodiversity and ecosystems.

A14.6 Building on this discussion, Table 14.9 and Table 14.10 list the 2050 Goals and 2030 Targets of the Post-2020 Global Biodiversity Framework that may be informed from the SEEA based accounts.

[168] See Proposed Headline Indicators of the Monitoring Framework for the Post-2020 Global Biodiversity Framework. CBD/WG2020/3/3/Add.1. Available at: https://www.cbd.int/doc/c/d716/da69/5e81c8e0faca1db1dd145a59/wg2020-03-03-add1-en.pdf.

[169] Ibid.

Table 14.9: Potential indicators for the 2050 Goals (incl. links to related SDG indicators)

Goal	Relevant SEEA accounts
A. The integrity of all ecosystems is enhanced, with an increase of at least 15% in the area, connectivity and integrity of natural ecosystems, supporting healthy and resilient populations of all species, the rate of extinctions has been reduced at least tenfold, and the risk of species extinctions across all taxonomic and functional groups, is halved, and genetic diversity of wild and domesticated species is safeguarded, with at least 90% of genetic diversity within all species maintained.	Goal A, which monitors the size of natural ecosystems and condition of ecosystem in terms of its connectivity and integrity as well as the status and trends of threaten species, can be informed by indicators from ecosystem extent accounts, ecosystem condition accounts and species accounts of the SEEA EA.
B. Nature's contributions to people have been valued, maintained or enhanced through conservation and sustainable use, supporting the global development agenda for the benefit of all people	Goal B, which monitors nature's contribution to people and benefits from ecosystem and biodiversity, and their sustainable use, can be informed by indicators from physical and monetary ecosystem services flows accounts of the SEEA EA
D. Means of implementation is available to achieve all goals and targets of the Framework.	Goal D, which monitors the means of implementation for the post-2020 framework, can be informed by indicators from the environmental protection expenditure accounts of the SEEA Central Framework

Table 14.10: Connecting SEEA accounts to the 2030 Targets

Target	Relevant SEEA accounts
2. Ensure that at least 20% of degraded freshwater, marine and terrestrial ecosystems are under restoration, ensuring connectivity among them and focusing on priority ecosystems.	Target 2, which monitors the area of degraded ecosystems under ecosystem restoration, can be informed by indicators deriving from a combination of ecosystem extent accounts and ecosystem condition accounts of the SEEA EA
3. Ensure that at least 30% globally of land areas and of sea areas, especially areas of particular importance for biodiversity and its contributions to people, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.	Target 3, which monitors the extent and condition of protected areas, can be informed by indicators from protect area accounts based on the SEEA EA.
4. Ensure active management actions to enable the recovery and conservation of species and the genetic diversity of wild and domesticated species, including through ex situ conservation, and effectively manage human-wildlife interactions to avoid or reduce human-wildlife conflict.	Target 4, which monitors management actions for the recovery and conservation of wild species of fauna and flora, can be informed by indicators from the species accounts of the SEEA EA. Indicators that measure the status and trend of species can also be integrated into ecosystem conditions of the SEEA EA to derive a broader measure of sustainability indicators
5. Ensure that the harvesting, trade and use of wild species is sustainable, legal, and safe for human health.	Target 5, which monitors the sustainable and safe harvesting and use of wild species of fauna, can be informed by indicators from physical ecosystem services flow account of the SEEA EA.

6. Manage pathways for the introduction of invasive alien species, preventing, or reducing their rate of introduction and establishment by at least 50%, and control or eradicate invasive alien species to eliminate or reduce their impacts, focusing on priority species and priority sites.	Target 6 which monitors the rate of invasive alien species can be integrated into the ecosystem condition accounts of the SEEA EA to derive a broader measures of sustainability indicator
7. Reduce pollution from all sources to levels that are not harmful to biodiversity, ecosystem functions or human health, including by reducing nutrients lost to the environment by at least half, and pesticides by at least two thirds and eliminating the discharge of plastic waste.	Target 7, which monitors the levels of population on ecosystem and biodiversity, can be informed by indicators deriving from a combination of ecosystem extent accounts of the SEEA EA and the residual flow accounts of the SEEA Central Framework.
8. Minimize the impact of climate change on biodiversity, contribute to mitigation and adaptation through ecosystem-based approaches, contributing at least 10 GtCO2e per year to global mitigation efforts, and ensure that all mitigation and adaptation efforts avoid negative impacts onbiodiversity.	Target 8, which monitors climate change mitigation and adaptation through nature-based solutions and ecosystems based approaches, can be informed by indicators from physical ecosystem services flow accounts of the SEEA EA.
9. Ensure benefits, including nutrition, food security, medicines,and livelihoods for people especially for the most vulnerable through sustainable management of wild terrestrial, freshwater and marine species and protecting customary sustainable use by indigenous peoples and local communities.	Target 9, which monitors the benefits from ecosystem and biodiversity for people, can be informed by indicators from a combination of physical and monetary ecosystem services flow accounts for the SEEA EA and socio-economic statistics.
10. Ensure all areas under agriculture, aquaculture and forestry are managed sustainably, in particular through the conservation and sustainable use of biodiversity, increasing the productivity and resilience of these production systems.	Target 10, which monitors the productivity, sustainability and resilience ecosystem and biodiversity from agricultural and other managed ecosystems, can be informed by indicators from a combination of ecosystem conditions and physical and monetary ecosystem services flows accounts for the cultivated/managed ecosystem of the SEEA EA.
11. Maintain and enhance nature's contributions to regulation of air quality, quality and quantity of water, and protection from hazards and extreme events for all people.	Target 11, which monitors the regulation of air and water flows and the mitigation of extreme events by ecosystem, can be informed by indicators from physical ecosystem services flow accounts of the SEEA EA.
12. Increase the area of, access to, and benefits from green and blue spaces, for human health and well-being in urban areas and other densely populated areas.	Target 12, which monitors the benefits from biodiversity and green/blue spaces for human health and well-being, can be informed by a combination of urban accounts, ecosystem condition accounts and physical ecosystem services flow accounts of the SEEA EA.
14. Fully integrate biodiversity values into policies, regulations, planning, development processes, poverty reduction strategies, accounts, and assessments of environmental impacts at all levels of government and across all sectors of the economy, ensuring that all activities and financial flows are aligned with biodiversity values.	Target 14, which monitors the status of integration and mainstreaming of biodiversity, can be informed by the global assessment of SEEA that measure the integration of biodiversity into national accounting and reporting systems, defined as implementation of SEEA.
16. Ensure that people are encouraged and enabled to make responsible choices and have access to relevant information and alternatives, taking into account cultural preferences, to reduce by at least half the waste and, where relevant the overconsumption, of food and other materials.	Target 16, which monitors the unsustainable consumption pattern, can be informed by footprint indicators deriving from environmental-extended input-output analysis using indicators from SEEA as the input data.

19. Increase financial resources from all sources to at least 200 billion per year, including new, additional and effective financial resources, increasing by at least 10 billion per year international financial flows to developing countries, leveraging private finance, and increasing domestic resource mobilization, taking into account national biodiversity finance planning, and strengthen capacity building and technology transfer and scientific cooperation, to meet the needs for implementing the post-2020 global biodiversity framework implementation, commensurate with the ambition of the goals and targets of the framework.	Target 19, which monitors the financial resources for the implementation for the post-2020 framework, can be informed by indicators from the environmental protection expenditure accounts of the SEEA Central Framework

Annex: *SEEALand* stylized example

Background

The stylised example described in this annex is intended to support the understanding and interpretation of the concepts described in the SEEA EA. Since there are a wide variety of combinations of ecosystem types and ecosystem services that will be present in different locations, there is no attempt here to present an example that might be considered universally applicable. Thus, this example demonstrates the accounting for a limited set of ecosystem types and ecosystem services. However, it is expected that the principles underpinning this limited example can be generalised to apply to more complex situations at the national level or for other ecosystem accounting areas.

In addition to the description of the example provided here, a complementary on-line spreadsheet is available on the SEEA website together with this publication.[170] This spreadsheet demonstrates more explicitly the accounting relationships and the relevant calculations. It is expected that, over time, this spreadsheet will be further developed to encompass of a wider range of accounting contexts.

In providing estimates in the accounts in this example, there is no direct connection made or implied to specific data sources. That is, it is assumed in the presentation here that account-ready data are available for incorporation into the accounts. Of course, this will generally not be the situation in practice, and significant work is likely to be needed to collect and organise relevant data for use in accounting, some of which will be outlined in the forthcoming *Guidelines on Biophysical Modelling for Ecosystem Accounting* and *Guidelines on the Valuation of Ecosystem Services and Ecosystem Assets.*

Finally, this example does not extend to the description of the range of accounts that could be compiled to complement the five main ecosystem accounts. For example, thematic accounts, such as the accounts for carbon, water or species, are not included. The development of such accounts to complement these ecosystem accounts may be developed in the on-line spreadsheet at a later stage.

General context and assumptions for the stylised example

The following ecosystem accounts have been compiled for the ecosystem accounting area (EAA) of "*SEEALand*." The opening of the accounting period for the accounts is 1 January 2020 and the closing of the accounting period is 31 December 2020.

There are six ecosystem types in *SEEALand* that are classified following the IUCN Global Ecosystem Typology Biomes and Ecosystem Functional Groups (EFG). For ease of explanation, short labels for each ecosystem type have been assigned as shown in the Table A.1 below.

Table A.1: List of ecosystem types for the *SEEALand* stylized example

Ref number	IUCN GET Biome / EFG	Short label in this example
#1	T2 Temperate-boreal forests and woodlands / T2.2 Deciduous temperate forests	Forest
#2	F2 Lakes / F2.1 Large permanent freshwater lakes	Lake
#3	T7 Intensive land use / T7.1 Annual croplands	Cropland
#4	T7 Intensive land use / T7.4 Urban and industrial ecosystems	Urban area
#5	TF1 Palustrine wetlands / TF1.3 Permanent marshes	Wetland
#6	M1 Marine shelf / M1.1 Seagrass meadows	Seagrass

[170] It can be accessed at https://seea.un.org/ecosystem-accounting.

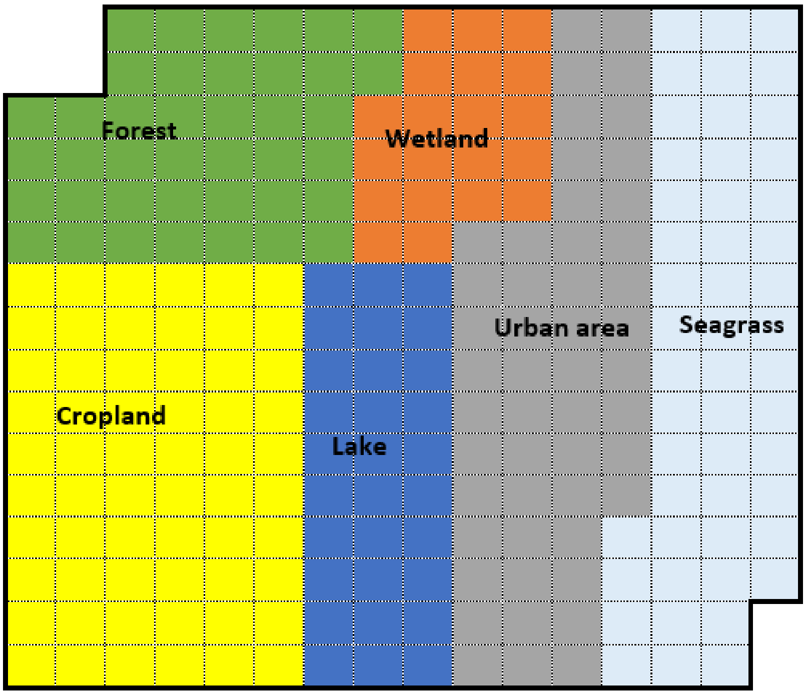
In terms of the changing ecological context, it is assumed that in *SEEAland* natural ecosystems have experienced increasing pressures reflected in (managed) conversions from forest to cropland and general intensification of ecosystem use. With respect to condition, this has had a negative impact on condition of forest and wetland, for example, because of edge effects impacting on the ecological functioning of the forest. Further, policies to improve the condition of cropland have had mixed outcomes and urban intensification is driving a loss of urban green spaces. In contrast, long-term efforts to improve the water quality of the lake have resulted in improving its condition. Finally, sewerage overflow from the urban area has negatively influenced the condition of seagrass beds.

These changes in condition also impact on changes in the future expected flows of ecosystem services, and hence on recorded measures of ecosystem degradation, ecosystem enhancement and reappraisals. Changes in future prices are also expected for some ecosystem services. For wood and wild fish provisioning services, increases in prices are driven by both increased demand and increased regulation of the sustainability of those industries that has decreased supply of ecosystem services. It is also expected that the price of global climate regulation services will increase reflecting increases in the marginal damages of carbon release.

Ecosystem Extent

At the opening of the accounting period there are six distinct ecosystem assets. The ecosystem assets are configured as shown in Figure A.1. The total area of *SEEALand* is 250 hectares (each grid cell represents 10 hectares).[171]

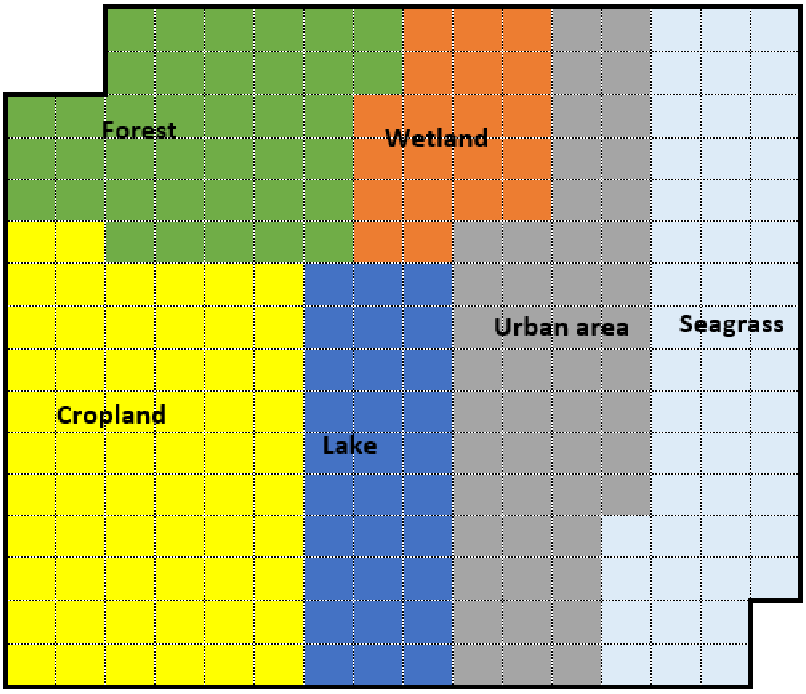
Figure A.1: Opening extent of ecosystem assets in *SEEALand*, 1 January 2020



[171] In practice, data on ecosystem extent are likely to be calculated a period of time (e.g., for the year 2020) rather than for specific days at the beginning and end of the accounting period. Given this situation it will be necessary to select the point in time to which the data should relate. For example, extent data for 2020 may be assumed to reflect the opening extent for the accounts of 2020 and extent data for 2021 may be assumed to reflect the closing extent for the accounts of 2020 (and the opening extent for the accounts of 2021).

Over the accounting period, there is one change in the extent of the ecosystem assets. It involves two hectares of forest being replaced by two hectares of cropland. This ecosystem conversion is considered a managed expansion of cropland and a managed reduction in forest.

Figure A.2: Closing extent of ecosystem assets in *SEEALand*, 31 December 2020



The following ecosystem extent account can be compiled based on the information in Figures A.1 and A.2. Entries concerning expansions and reductions are based on the changes in the maps of ecosystem extent and the context for those changes. Where there is no information to determine whether a change is managed or unmanaged, it is appropriate to record only the total expansion or reduction.

Table A.2: Ecosystem extent account, 2020 (hectares)

	Ecosystem types						
Accounting entries	Forest	Lake	Cropland	Urban area	Wetland	Seagrass	Total
Opening extent	**40**	**30**	**60**	**50**	**20**	**50**	**250**
Additions to extent							
Managed expansions			2				2
Unmanaged expansions							
Reduction to extent							
Managed reductions	2						2
Unmanaged reductions							
Net change in extent	-2	0	+2	0	0	0	0
Closing extent	**38**	**30**	**62**	**50**	**20**	**50**	**250**

An ecosystem extent change matrix can also be compiled, as presented in Table A.3. It is designed to record which ecosystem types have been converted to which other ecosystem types. The matrix is compiled in four steps. In step 1, the opening extent for each ecosystem type is recorded in the right hand column. In step 2, the closing extent for each ecosystem type is recorded in the bottom row. In step 3, the areas of an ecosystem type that have not been converted to another ecosystem type over the accounting period are recorded along the diagonal. In this example there has only been one ecosystem type, forest, where there is less area, and hence for all other ecosystem types the unchanged area is the same as the opening extent.

In step 4, entries are made for changes in extent, one entry is made for each change. The entries are made from the perspective of the closing extent and the ecosystem type that increased in area. Thus, in this example, since the area of cropland increased by 2, an entry in made in the cropland column corresponding to the ecosystem type that changed, in this case forest. With regard to this conversion the interpretation is that for forests (reading along the first row) 38 hectares are unchanged but 2 hectares are now cropland. Also, for cropland (reading down the fourth column), 60 hectares are unchanged and an additional 2 hectares have been added that were formerly forest

Table A.3: Ecosystem type change matrix, 2020 (hectares)

		Ecosystem types - Closing						**Opening extent**
		Forest	Lake	Cropland	Urban areas	Wetland	Seagrass	
Ecosystem types – Opening	Forest	38		2				**40**
	Lake		30					**30**
	Cropland			60				**60**
	Urban areas				50			**50**
	Wetland					20		**20**
	Seagrass						50	**50**
	Closing extent	**38**	**30**	**62**	**50**	**20**	**50**	**250**

Ecosystem Condition

To measure the condition of each ecosystem asset, the ecosystem condition typology is used to structure the relevant characteristics and variables following the approach described in Chapter 5. The intent in the selection of characteristics and variables is to measure each ecosystem's integrity. This is done by identifying relevant abiotic, biotic and landscape/seascape characteristics. These characteristics will encompass information about biodiversity and also link to the capacity for the ecosystem to supply ecosystem services.

By way of example, for forest the abiotic characteristics are assessed using three variables: vegetation water content, soil organic carbon stock and foliar nitrogen concentration, each of these describing the physical and chemical state of the ecosystem. The biotic characteristics of the forest are assessed using the variables trees species richness, tree cover and the NDVI vegetation index, each of these describing the composition, structure and function of the ecosystem. Forest area density is used to assess landscape characteristics. Collectively, these seven variables will provide a good assessment of the ecosystem integrity of the forest.

The characteristics are structured following the SEEA Ecosystem Condition Typology (ECT) and following the selection criteria described in Annex 5.1. Relevant condition characteristics, variables, indicators and reference levels for each ET and associated stylised values are presented in the complementary spreadsheet, sheet "Condition accounts by ET", including a short discussion on the selection of characteristics and indicators in the context of this stylised example.

By way of example, Table A.4 presents the three condition accounts for the forest, i.e. the condition variable account (Table A.4a), the condition indicator account (Table A.4b) and the condition index account (Table A.4c). Columns 1 and 2 in each account show the structure of the SEEA ECT which is the same for all ET. Column 3 in each account shows the selected variables for each ECT class. One or more variables may be included for each class following the general advice provided in Chapter 5. Column 4 in the variable and indicator accounts shows the measurement unit for the selected variable.

In the ecosystem variable account, columns 5 and 6 record the observed variable values at the opening and closing of the accounting period. Column 7 shows the change over the accounting period.

In the ecosystem indicator account, columns 5 and 6 show the variable values from the ecosystem variable account and columns 7 and 8 record the the lower and upper reference levels for each variable which are determined based on the agreed reference condition (see Annex 5.2). In this example, the forest, lake, wetland and seagrass are assessed in relation to natural reference conditions, while cropland and urban area are assessed in relation to anthropogenic reference conditions. The entries in columns 9 and 10 are the derived opening and closing values for the condition indicators after normalising the variable values based on the reference levels. Column 11 shows the change in the indicator value between opening and closing values.

In the ecosystem index account, columns 9 and 10 show the indicator values from the ecosystem indicator account. Column 12 records the weight for each indicator in the overall index for the ecosystem. In this example, the overall condition index is derived based on equal weighting of each of the ECT classes used to compile the index.[172] Usually 6 ECT classes are measured thus the weight for each class is 0.17. Where there is more than one variable in an ECT class, each variable is also equally weighted within that class to form the sub-index. Thus, for forest the sub-index for chemical state is derived using an equal weight of the two component variables. Columns 13 and 14 record the derived opening and closing index values for each characteristic and the associated sub-indices and total index. Column 15 records the changes in index values.

Table A.4a: Ecosystem variable condition account for forests, 2020

SEEA Ecosystem Condition Typology Class		Variable descriptor	unit	Variable values (observed)		
				Opening	Closing	Change
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Abiotic characteristics	Physical state	Vegetation water content - NDWI	index (-1 to 1)	0.31	0.29	-0.02
	Chemical state	Soil organic carbon stock	tC/ha	100	95	-5
		Foliar or litter nitrogen concentration	mg N / g dry weight	18	17	-1
Biotic characteristics	Compositional state	Tree species richness	number	6	5	-1
	Structural state	Tree cover	%	81	75	-6
	Functional state	Vegetation index - NDVI	index (-1 to 1)	0.65	0.63	-0.02
Landscape/seascape characteristics		Forest area density	%	74	59	-15

[172] Section 5.4.2 provides a discussion on potential aggregation functions an weights. It is noted here that an area-weighted approach has been used meaning that the overall index is invariant to whether the data are collated at finer resolutions (e.g. pixels) or at larger resolutions (e.g. for the ecosystem asset).

Table A.4b: Ecosystem indicator condition account for forests, 2020

SEEA Ecosystem Condition Typology Class		Variable descriptor	Measurement unit	Variable values (observed)		Reference level values		Indicator values (rescaled)		
				Opening	Closing	Lower level	Upper level	Opening	Closing	Change
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Abiotic characteristics	Physical state	Vegetation water content - NDWI	index (-1 to 1)	0.31	0.29	-1	1	0.66	0.65	-0.01
	Chemical state	Soil organic carbon stock	tC/ha	100	95	0	250	0.40	0.38	-0.02
		Foliar or litter nitrogen concentration	mg N / g dry weight	18	17	4	40	0.39	0.36	-0.03
Biotic characteristics	Compositional state	Tree species richness	number	6	5	0	10	0.60	0.50	-0.10
	Structural state	Tree cover	%	81	75	0	100	0.81	0.75	-0.06
	Functional state	Vegetation index - NDVI	index (-1 to 1)	0.65	0.63	-1	1	0.83	0.82	-0.01
Landscape/seascape characteristics		Forest area density	%	74	59	0	100	0.74	0.59	-0.15

Table A.4c: Ecosystem index condition account for forests, 2020

SEEA Ecosystem Condition Typology Class		Variable descriptor	Indicator values (0 - 1)		Indicator weight	Index values		
			Opening	Closing		Opening	Closing	Change*
(1)	(2)	(3)	(9)	(10)	(12)	(13)	(14)	(15)
Abiotic characteristic	Physical state	Vegetation water content - NDWI	0.66	0.65	0.17	0.11	0.11	0.00
	Chemical state	Soil organic carbon stock	0.40	0.38	0.08	0.03	0.03	0.00
		Foliar or litter nitrogen concentration	0.39	0.36	0.08	0.03	0.03	0.00
	Total abiotic				0.33	**0.17**	**0.17**	**-0.01**
Biotic characteristics	Compositional state	Tree species richness	0.60	0.50	0.17	0.10	0.08	-0.02
	Structural state	Tree cover	0.81	0.75	0.17	0.14	0.13	-0.01
	Functional state	Vegetation index - NDVI	0.83	0.82	0.17	0.14	0.14	0.00
	Total biotic				0.50	**0.37**	**0.34**	**-0.03**
Landscape/seascape characteristics		Forest area density	0.74	0.59	0.17	0.12	0.10	-0.03
	Total landscape/seascape					**0.12**	**0.10**	**-0.03**
Total					1.00	**0.67**	**0.61**	**-0.06**

* Changes in index values are derived as the difference between opening and closing index values. Due to rounding, this may differ from the result obtained from weighting the change in indicator values.

The complementary spreadsheet shows how these three condition accounts can be combined into a single table. This alternative presentation may be useful in some contexts.

Table A.5 shows the ecosystem condition indices and sub-indices for each of the six ET in this example using the opening and closing index values and associated changes in those values as derived in the spreadsheet. An average measure of ecosystem condition across all ET has not been derived as this would imply aggregation across different reference conditions and this is not recommended.

As noted above, additional detail for each of the condition accounts is provided in the complementary spreadsheet. The spreadsheet also provides a short discussion on the selection of characteristics for each ET. In summary, and following the general ecological context for *SEEALand* introduced above, the changes in condition for each ET recorded in Table A.5 reflect:

- **Forest**: A substantial area of forest has previously been cleared for cropland and there has been a further small conversion in this accounting period. This results in a large decrease in forest area density, a proxy for forest connectivity. Tree cover has declined as well. Other condition variables exhibit smaller changes.
- **Lake**: A long-term action plan on nutrient management leads to a further improvement in lake condition, starting from an already good quality.
- **Wetland**: Sewerage overflow from urban wastewater treatment plants and intensive land use continues to affect the water quality of the wetland.
- **Cropland**: Cropland is slowly degrading through intensive use although there is a policy to increase organic farming practices.
- **Urban ecosystem:** The account shows slightly declining conditions of the urban ecosystem over the accounting period related to a loss of urban green area.
- **Seagrass**: The seagrass beds are under pressure from sewerage overflow from the urban area and the associated organic pollution.

Table A.5: Ecosystem condition indices account by ecosystem type

	Ecosystem types					
Accounting entries	Forest	Lake	Cropland	Urban area	Wetland	Seagrass
Opening condition value	**0.67**	**0.63**	**0.47**	**0.50**	**0.59**	**0.45**
Change in abiotic ecosystem characteristics	-0.01	0.02	0.00	0.01	-0.02	-0.03
Change in biotic ecosystem characteristics	-0.03	0.03	0.01	-0.02	0.00	-0.03
Change in landscape level characteristics	-0.03	0.00	0.00	-0.01	-0.01	-0.02
Net change in condition	**-0.06**	**0.05**	**0.00**	**-0.02**	**-0.04**	**-0.08**
Closing condition value	**0.61**	**0.67**	**0.47**	**0.49**	**0.56**	**0.37**

In this example there has been one conversion during the accounting period from forest to cropland. Following the advice provided in Chapter 5, the measurement of condition at the opening and closing of the accounting period should relate to the area of the ecosystem at that point in time. Consequently, in this example the measure of closing condition for forest will relate to a smaller area of forest than the measure of opening condition. The opposite is true for cropland.

Accepting that conversions will occur, an approach is needed to accommodate the effect of the change in extent, and to make the opening and closing measures of condition comparable. The general approach (and the approach applied in this example) when (i) accounting at relatively large scales, e.g., at catchment scale or larger, and (i) conversions are relatively small (e.g., <5% of total area); is to incorporate characteristics for the measurement of condition that are sensitive to changes in extent, for example tree cover and share of lake shoreline with natural vegetation.

At the same time, where there are significant conversions among ET during an accounting period or where accounting is undertaken for small areas, it is likely to be necessary to explicitly distinguish changes in ecosystem extent and to assess changes in ecosystem condition more carefully. Where data are available, a useful approach is to measure condition for the area of the ET that remains unchanged over the accounting period separately from the area that has been converted. This approach may be most readily applied when using data that are mapped to individual pixels and hence the condition of unconverted and converted areas can be distinguished.

Ecosystem services

The ecosystem services supplied by the various ecosystem types are shown in Table A.6. The corresponding use of these ecosystem services is shown in Table A.7. All flows are treated as final ecosystem services, i.e., they are recorded as flowing from ecosystem assets direct to economic units. There are no imports or exports of services to be recorded and there are no intermediate services between ecosystem assets to be recorded.

Table A.6: Ecosystem services supply and use account in physical terms – supply table, 2020

SUPPLY			UNITS OF MEASURE		Forest	Lake	Cropland	Urban area	Wetland	Seagrass	Total Supply resident ecosystem assets	Supply from non-resident ecosystem assets - Imports: Final	Supply from non-resident ecosystem assets - Imports: Intermediate	TOTAL SUPPLY
Selected ecosystem services														
Provisioning services														
	Biomass provisioning	Crop provisioning	tonnes				150				150	0	0	150
		Wood provisioning services	m^3		140						140	0	0	140
		Wild fish and other natural aquatic biomass provisioning services	tonnes			3				6	9	0	0	9
Regulating and maintenance services														
	Global climate regulation services		tonnes CO_2		150			5	20	250	425	0	0	425
	Water purification services		tonnes N removed						7		7	0	0	7
Cultural services														
	Recreation-related services		# visits		1,500	5,000		2,500		800	9,800	0	0	9,800

NB: Resident ecosystem assets are those ecosystem assets located within the ecosystem accounting area. Non-resident ecosystem assets are located outside the ecosystem accounting area.

Table A.7: Ecosystem services supply and use account in physical terms – use table, 2020

USE		UNITS OF MEASURE	Agriculture	Forestry	Fisheries	Electricity, gas, steam and air conditioning supply	Total Industry	Government consumption	Household consumption	Total Use by resident economic units	Exports - final ecosystem services	Total Use by economic units	Forest	Lake	Cropland	Urban area	Wetland	Seagrass	Total use resident ecosystem assets	Exports - intermediate services	Total Use by ecosystem assets	TOTAL USE
Selected ecosystem services																						
Provisioning services																						
Biomass provisioning	Crop provisioning	tonnes	150				150			150		150							0	0	0	150
	Wood provisioning services	m^3		140			140			140		140							0	0	0	140
	Wild fish and other natural aquatic biomass provisioning services	tonnes			9		9			9		9							0	0	0	9
Regulating and maintenance services																						
Global climate regulation services		tonnes CO_2					0	425		425		425							0	0	0	425
Water purification services		tonnes N removed				7	7			7		7							0	0	0	7
Cultural services																						
Recreation-related services		# visits					0		9,800	9,800		9,800							0	0	0	9,800

NB: Resident ecosystem assets are those ecosystem assets located within the ecosystem accounting area. Non-resident ecosystem assets are located outside the ecosystem accounting area.

Ecosystem service flows in monetary terms are estimated by multiplying the physical flow of the service recorded in Tables A.6 and A.7 by relevant prices for each service reflecting their exchange values. They are recorded in Tables A.8 and A.9 which presents the supply and use tables in monetary terms.

The following prices have been assumed in deriving the monetary supply and use entries. Commonly, prices for wood, crop and wild fish provisioning services would be derived using directly observed values (e.g. stumpage values for wood, land rental prices) or residual value and resource rent methods. Global climate regulation services are more commonly estimated using data from carbon trading schemes or data on the social cost of carbon (under appropriate assumptions). Water purification services may be estimated using replacement cost techniques and recreation-related services using data from travel cost methods. These various techniques are described in Chapter 9.

Wood provisioning	\$60 / m^3
Crop provisioning	\$75 / tonne
Wild fish biomass provisioning	\$350 / tonne
Global climate regulation	\$25 / tonne of CO_2
Water purification	\$100 / tonne of nitrogen removed
Recreation-related	\$5 / visit

The aggregate Gross Ecosystem Product (GEP) is equal to the sum of the value of all final ecosystem services less net imports of intermediate services. Since there are no intermediate services in this example, GEP is equal to \$83,125.

Table A.8: Ecosystem services supply and use account in monetary terms – supply table, 2020

SUPPLY				Forest	Lake	Cropland	Urban area	Wetland	Seagrass	Total Supply resident ecosystem assets	Supply from non-resident ecosystem assets - Imports: Final	Supply from non-resident ecosystem assets - Imports: Intermediate	TOTAL SUPPLY
Selected ecosystem services													
Provisioning services													
	Biomass provisioning	Crop provisioning				11,250				11,250	0	0	11,250
		Wood provisioning services		8,400						8,400	0	0	8,400
		Wild fish and other natural aquatic biomass provisioning services			1,050				2,100	3,150	0	0	3,150
Regulating and maintenance services													
	Global climate regulation services			3,750			125	500	6,250	10,625	0	0	10,625
	Water purification services							700		700	0	0	700
Cultural services													
	Recreation-related services			7,500	25,000		12,500		4,000	49,000	0	0	49,000
TOTAL SUPPLY				**19,650**	**26,050**	**11,250**	**12,625**	**1,200**	**12,350**	**83,125**	**0**	**0**	**83,125**

Table A.9: Ecosystem services supply and use account in monetary terms – use table, 2020

USE			Agriculture	Forestry	Fisheries	Electricity, gas, steam and air conditioning supply	**Total Industry**	Government consumption	Household consumption	**Total Use by resident economic units**	Exports - final ecosystem services	**Total Use by economic units**	Forest	Lake	Cropland	Urban area	Wetland	Seagrass	**Total use resident ecosystem assets**	Exports - intermediate services	**Total Use by ecosystem assets**	**TOTAL USE**
Selected ecosystem services																						
Provisioning services																						
	Biomass provisioning	Crop provisioning	11,250				11,250			11,250		11,250							0	0	0	11,250
		Wood provisioning services		8,400			8,400			8,400		8,400							0	0	0	8,400
		Wild fish and other natural aquatic biomass provisioning services			3,150		3,150			3,150		3,150							0	0	0	3,150
Regulating and maintenance services																						
	Global climate regulation services							10,625		10,625		10,625							0	0	0	10,625
	Water purification services					700	700			700		700							0	0	0	700
Cultural services																						
	Recreation-related services								49,000	49,000		49,000							0	0	0	49,000
TOTAL USE			**11,250**	**8,400**	**3,150**	**700**	**23,500**	**10,625**	**49,000**	**83,125**	**0**	**83,125**							**0**	**0**	**0**	**83,125**

The entries for ecosystem services in the physical and monetary ecosystem service flow accounts shown above concern actual ecosystem service flows supplied and used during the accounting period. For the compilation of the monetary ecosystem asset account, it is necessary to estimate expected ecosystem service flows at the opening and closing of the accounting period. At the opening of the accounting period, expected flows will usually be based on past ecosystem service flows and the understanding of ecosystem condition and likely changes in condition at that time. At the closing of the accounting period, the actual flows during the accounting period will be brought into consideration as well as changes in condition that would affect the capacity to supply services.

Assuming the changes in condition are relatively gradual and other potential drivers (such as changes in population) are steady, measures of expected flows would not change significantly over an accounting period and may be quite closely aligned with the actual ecosystem service flows during the accounting period.

For *SEEALand*, the expected physical flows and expected prices at the opening and closing of the accounting period are shown in the complementary spreadsheet. In summary, there are a range of small differences between the expected flows at the opening of the accounting period and the actual flows recorded during the period. At the closing of the accounting period, the expected flows are lower for wood provisioning, global climate regulation and recreation-related services for forests reflecting the ecosystem conversion that took place. An increase in crop provisioning services is also expected. A small decline in global climate regulation services from wetlands is expected reflecting its decline in condition while there is a small rise in ecosystem services from lakes reflecting their improvement in condition. Recreation related services for urban areas are expected to increase due to larger populations but decline for seagrass due to the decline in condition.

Concerning expected prices, they are expected to remain the same for crop provisioning, water purification and recreation-related services. They are expected to increase for wood and wild fish provisioning driven by both increased demand and increased regulation of the sustainability of those industries. It is also expected that the price of global climate regulation services will increase reflecting increases in the marginal damages of carbon release.

Monetary ecosystem asset account

Estimates of opening and closing asset values are estimated for each ecosystem type covering all relevant ecosystem services. As explained in various places through the SEEA EA, the monetary values recorded in this table cannot be interpreted as reflecting a complete or universal measure of the value of nature since it excludes a range of values, such as intrinsic values, that may be ascribed to ecosystems, and may not be quantified in monetary terms.

In deriving the estimate of the net present value, the following assumptions are made:

- Asset life is 100 years;
- A constant flow of ecosystem services and constant price of ecosystem services over the asset life (as noted above, some changes in expected physical flows and prices have been incorporated reflecting changed expectations between the opening and closing of the accounting period, in part as a result of the ecosystem conversions);
- No further ecosystem conversions to the closing extent on 31 December 2020;
- Discount rate of 2% in real terms for all ecosystem services; and
- Income earned at the end of the accounting period.

The workings for each ecosystem type in terms of future ecosystem flows and prices and resultant NPV are shown in the spreadsheet in the sheet “NPV by ET”. The following Table A.10 shows the structure of information used to compile the NPV for the forest.

Table A.10: NPV calculations for Forest, 2020

Expected physical flows	Wood provisioning (m^3)	150	120
	Global climate regulation (tonnes CO_2	160	125
	Recreation-related (# visits)	1,600	1,450
Expected prices	Wood provisioning	$60	$65
	Global climate regulation	$25	$26
	Recreation-related	$5	$5
Expected exchange value	Wood provisioning	$9,000	$7,800
	Global climate regulation	$4,000	$3,250
	Recreation-related	$8,000	$7,250
	Total	**$21,000**	**$18,300**
Net present value	Wood provisioning	$387,885	$336,167
	Global climate regulation	$172,393	$140,070
	Recreation-related	$344,787	$312,463
	Total	**$905,065**	**$788,700**
Change in NPV			**-$116,366**

The entries in the monetary ecosystem asset account, Table A.11, are derived following the principles described in Chapter 10 and the steps described in Annex 10.1 for the decomposition of the change in asset values. The following key points can be drawn from the monetary ecosystem asset account about *SEEALand*:

- The asset value of the Lake has the highest proportion of the overall value of ecosystem assets;
- Ecosystem degradation has been recorded for Forest, Wetland and Seagrass reflecting their decline in condition and associated decline in expected ecosystem service flows;
- The ecosystem conversion from Forest to Cropland has a net negative effect on these asset values; and
- The revaluations reflecting the changes in expected prices for ecosystem services can be seen to affect all ecosystem types (except Cropland where the prices for the only ecosystem service – crop provisioning – did not change).

Table A.11: Monetary ecosystem asset account, 2020

	Forest	Lake	Cropland	Urban area	Wetland	Seagrass	**TOTAL**
Opening value	$905,065	$1,078,321	$484,856	$522,568	$51,718	$529,679	$3,572,207
Ecosystem enhancement	$0	$15,300	$0	$0	$0	$0	$15,300
Ecosystem degradation	-$108,111	$0	$0	$0	-$1,099	-$163,946	-$273,156
Ecosystem conversions							
Additions	$0	$0	$16,944	$0	$0	$0	$16,944
Reductions	-$43,435	$0	$0	$0	$0	$0	-$43,435
Other changes in volume of ecosystem assets							
Catastrophic losses							
Upward reappraisals	$0	$0	$47,704	$43,098	$0	$0	$90,802
Downwards reappraisals	$0	$0	$0	$0	$0	$0	$0
Revaluations	$35,180	$47,624	$0	$215	$840	$160,929	$244,789
Net change in value	-$116,366	$62,924	$64,648	$43,314	-$259	-$3,017	$51,244
Closing value	$788,700	$1,141,244	$549,504	$565,881	$51,459	$526,662	$3,623,451

Research and development agenda

The SEEA EA provides a consistent accounting framework for delineating and measuring ecosystems. Data compiled using SEEA EA are invaluable inputs for the evaluation of policy and analysis of environmental and economic issues. As environmental and economic contexts change, as understanding of the links between the environment and the economy develops, and as policy and analytical requirements evolve, the SEEA EA must be reviewed to ensure its ongoing relevance.

In addition, as implementation of the SEEA EA occurs increasingly across the world, the range of experience gained will offer new insights in the measurement of ecosystem assets and services that should be considered in the conceptualization of the environmental and economic accounts.

As the accounting basis for the SEEA EA is the SNA, developments in accounting within the context of that international standard will also need to be considered. The research agenda for the SNA is presented in annex 4 of the 2008 SNA and a new program of work is under consideration. Of particular relevance in this regard, is the expanding range of new economic instruments that are being created and implemented as part of policies for managing the environment. The research agendas of the SEEA EA, the SEEA Central Framework and the SNA need to reflect these developments.

The process for reviewing and updating the SEEA EA will follow standard processes that have developed for the review of international standards. Thus, there will be consideration within the United Nations statistical system of (a) the relative importance of updating the standard to ensure its ongoing relevance; (b) the consequences of making any changes and the potential impact on implementation; and (c) the extent to which research into a proposed area of change has been completed. The process for selecting topics for investigation and determining the appropriate changes to the SEEA EA will involve widespread consultation and will involve both compilers and users of ecosystem accounts.

Since the SEEA EA is an integrated accounting system with links among different accounts, changes in individual areas in response to specific concerns is likely to have broader ramifications. As well, SEEA EA has strong links to other emerging areas of statistics beyond accounting, such as concerning geospatial statistics. Hence, updating the standard must be completed in a coordinated and integrated fashion.

Described below are the major topics identified during the revision of the SEEA EEA as being those that would benefit from further consideration within the international statistical community. These topics concern both conceptual issues and issues about methods and implementation. The topics listed below are categorized broadly and will need to be detailed and refined through further discussion ahead of the commencement of research work. Additional topics may also be proposed in due course.

- Topics concerning conceptual issues
  - Description and measurement of ecosystem capacity
  - Classification of ecosystem services
  - Treatment of the atmosphere
  - Connections to complementary valuations of ecosystem services and ecosystem assets
  - Ongoing alignment with the SNA
- Topics concerning methods and implementation
  - Further adapting measurement techniques to support implementation
  - Data standards and availability

Applications and indicators

In addition, research and development in some of these areas might be usefully combined with work on the research agenda of the SEEA Central Framework. Specifically, research work on accounting for soil resources, the valuation of water resources, and the development of land-cover and land-use classifications could be considered jointly.

A regular review of the research and development agenda, including setting the priorities for work, will be undertaken by the UNCEEA. An important aspect in advancing this work will be the co-ordination of research and testing, recognising the differences between countries in terms of resources, data and complexity of environmental, social and economic context.

The advancement of the research and development agenda will be undertaken under the auspices of the UNCEEA but it is expected that it will involve substantive collaboration with experts and stakeholders well beyond the statistical community, in keeping with the spirit of development of the SEEA EA itself. Beyond work within the national and international public sectors, it is also expected that there will be active participation from the academic community and from environmental and sustainability focused organisations. Further, collaboration with advances underway in accounting for natural capital in the corporate sector should be pursued.

The outputs of work on the topics below may emerge in a number of forms including published research papers, technical guidance and notes and training materials. Ultimately, a revision of the SEEA EA would be considered at an appropriate time in the same way that all statistical standards are updated to reflect current best practice.

Topics on conceptual issues

Description and measurement of ecosystem capacity

The SEEA EA provides a definition of ecosystem capacity in terms of the ability of ecosystem assets to supply individual ecosystem services without reducing ecosystem condition. This is a meaningful and implementable definition. Nonetheless, the discussion of ecosystem capacity highlights a general conceptual preference for a more systemic approach that takes into consideration relationships among ecosystem services and among ecosystem assets.

Building on the initial discussion of a systemic approach to the definition and measurement of ecosystem capacity, further research on this topic is appropriate. In particular, the research should consider the links between the concept of ecosystem capacity and ecosystem condition; examine the implications of a systemic definition of ecosystem capacity for the definition and measurement of ecosystem degradation, ecosystem enhancement and other changes in the value of ecosystem assets; and assess the potential of a systemic definition of ecosystem capacity to better articulate the ways in which ecosystem accounting can support discussion of ecosystem resilience, the maintenance of ecosystem function and the measurement of ecological thresholds and limits.

Classification of ecosystem services

The SEEA EA provides a reference list of ecosystem services including 33 main ecosystem services and agreed labels and descriptions. This reference list will support the development of methods, the sharing of knowledge and experience and the comparison of estimates of ecosystem services. The reference list was developed in collaboration with experts who have led the development of a range of ecosystem service classifications and typologies including CICES, NESCS, TEEB and IPBES-NCP. However, it was not possible during the revision process to establish an agreed classification of ecosystem services for ecosystem accounting purposes that satisfied general principles for a statistical classification.

Correspondences between the reference list and the existing range of classifications and typologies have been developed and are available as an online annex to the SEEA EA. These can serve as the basis for advancing work towards an internationally agreed classification of ecosystem services for statistical purposes.

Treatment of the atmosphere

Both the SEEA EA and the SEEA Central Framework exclude measurement of the atmosphere from the scope of environmental assets. In the case of the SEEA EA, this reflects a focus on the biosphere, and in the case of the SEEA Central Framework, this reflected a lack of potential to quantify the atmosphere in a meaningful way for accounting purposes. At the same time, both documents recognise the relevance of the atmosphere as part of the environment, for example in terms of the importance of air quality and the role of the atmosphere as a sink for greenhouse gas emissions.

Further work is needed to articulate how the atmosphere and its functions may be appropriately characterised in accounting terms. This work should consider how the atmosphere might be partitioned into relevant spatial units; how the condition of the atmosphere might be assessed; whether there are ecosystem services provided by the atmosphere; and how transactions related to the atmosphere, for example transactions related to reducing greenhouse gas emissions, are most appropriately recorded. Research on this topic must link to related work in the context of the SEEA Central Framework and the SNA.

Connections to complementary valuations of ecosystem services and ecosystem assets

The SEEA EA provides a clear valuation concept (i.e., exchange values) and a clear measurement boundary related to ecosystem services, that supports a consistent approach to the monetary valuation of ecosystem services and ecosystem assets for accounting purposes. The concept of exchange values is well-established in national accounting but it has been less commonly applied in environmental valuation, where alternative economic valuation perspectives are used.

Further discussion is appropriate, based on the concepts described in the SEEA EA and the complementary valuation measures described in chapter 12, to further refine and communicate the connections between exchange value based estimates from the ecosystem accounts and other approaches to valuation of the environment. A particular focus should be on ensuring appropriate application and interpretation of different valuation concepts in different decision making contexts. This work may consider complementary valuations such as the measurement of consumer surplus and changes in welfare; the assessment of ecosystem disservices and negative externalities; non-use values; wealth accounting based on shadow prices and restoration cost based approaches to the measurement of ecosystem degradation. Work on this topic should be undertaken in consultation with SNA experts.

Ongoing alignment with the SNA

A motivation in the conceptual design of the SEEA EA is the potential to compare and align estimates from the ecosystem accounts with measures of income and wealth from the SNA. As economic and environmental contexts change, all statistical standards are subject to reconsideration and hence to ensure the ongoing alignment between the SEEA EA and the SNA there are a number of emerging asset boundary issues that deserve ongoing and joint consideration among relevant experts. In a number of cases, these issues are emerging because of ongoing changes in institutional arrangements and markets structures in response to the effects of climate change and other environmental challenges. The issues include the treatment of stranded assets such as fossil fuel reserves, the valuation of water resources, the valuation of renewable resources; the treatment of payments for ecosystem services and transactions in environmental markets; and the recognition of liabilities in the context environmental damage.

In addition, further engagement with national accounts experts would be beneficial in the area of the treatment of public goods and the recording of relevant transactions, for example, concerning collective consumption and social transfers in kind. These topics are of relevance in the allocation of the use of some ecosystem services and in the design of the sequence of institutional sector accounts. The update of the 2008 SNA provides an excellent opportunity to address some of the issues above.

Topics on methods and implementation

Further adapting measurement techniques to support implementation

There are many measurement components across the conceptual framework of the ecosystem accounts. There are also well-established measurement approaches for these components covering the delineation of ecosystem types, the measurement of ecosystem condition and the measurement of ecosystem services flows. At the same time, the adaptation of these approaches to the requirements of ecosystem accounting is relatively recent and it is expected that there would be further testing and development of measurement techniques in all areas of ecosystem accounting as part of the wider implementation process.

Work in this area should build from the technical guidance on ecosystem accounting.[173] Specific areas of focus in the testing and developments of methods for accounting in physical terms concern:

- Delineation of ecosystem assets, especially in relation to the measurement of change over time and the identification of ecosystem conversions;
- Selection of a minimum set of ecosystem condition variables and determination of reference levels and conditions in different ecosystem types along a gradient from natural to anthropogenic;
- Articulation of relationships between ecosystem condition variables, ecosystem characteristics and processes and measures of ecosystem services;
- Spatial modelling of ecosystem services, especially with respect to use of ecosystem services and relative to ecosystem capacity;
- Methods to accounting for specific ecosystem types e.g., oceans, urban areas and wetlands.

Areas of focus in the testing and development of methods for accounting in monetary terms concern:

- Collection of data on ecosystem services by ecosystem type and taking into account the location of users and variations in institutional arrangements;
- Application of value transfer techniques for accounting purposes, in particular considering alignment with exchange value concepts, consistency with data collected in physical terms on extent, condition and service flows and advancement of the potential of value generalisation techniques;

[173] In particular, the *Guidelines on Biophysical Modelling for Ecosystem Accounting* (UNSD, n.d.-a, forthcoming) and the *Guidelines on the Valuation of Ecosystem Services and Ecosystem Assets* (UNSD, n.d.-b, forthcoming).

- Approach to the measurement of future flows and prices of ecosystem services as input to the calculation of net present values for ecosystem assets; and
- Interpretation of the data from the ecosystem accounts in monetary terms.

Data standards and availability

The compilation of ecosystem accounts will involve the collation and integration of a wide variety of data, many of which may be unfamiliar to statistical offices. As part of the implementation process, the development of shared data tools, frameworks to assess data quality, and expectations on quality would be a significant platform. Areas of focus in this work include:

- Principles and practices for the development of infrastructure for spatial data to support ecosystem accounting;
- Determination of a minimum set (tier 1) of account ready data;
- Principles and practices for accessing and sharing data including tools to support the interoperability of data and systems;
- Bridge tables and cross-walks from SEEA EA reference classifications and lists for ecosystem types and ecosystem services to other related classifications, lists and typologies;
- Development of spatial sampling methods and strategies; and
- Articulation of data quality assessment frameworks, tools and process, especially concerning spatial data.

Applications and indicators

Section E of the SEEA EA provides an introduction to a range of complementary presentations, thematic accounts and indicators that demonstrate the potential to use ecosystem accounts data to support decision making. As part of a wider implementation program, the advancement of applications and indicators building on ecosystem accounting can be continued. Specific areas of focus include:

- The development of guidance for SEEA-based thematic accounts for biodiversity, climate change, oceans and urban areas;
- The design of global accounts that incorporate data within and beyond national jurisdictions for example concerning oceans and the atmosphere;
- The description of aggregates and indicators based on the SEEA EA and related data to support environmental monitoring and reporting. This includes the development of aggregate indices of ecosystem condition, indicators linking ecosystem accounting data to data on economic production, employment and restoration expenditure, indicators to support global environmental conventions including the CB), the UNCCD and the UN UNFCCC.

Glossary

A

Abiotic flows are contributions to benefits from the environment that are not underpinned by, or reliant on, ecological characteristics and processes. (para. 6.35)

Anthropogenic ecosystems are predominantly influenced by human activities where a stable natural ecological state is unobtainable and future socio-economic interventions are required to maintain a new stable state. (Table 5.7)

B

Balance sheet is a statement, drawn up in respect of a particular point in time, of the values of assets owned and of the liabilities owed by an institutional unit or group of units. (2008 SNA, para. 13.2)

Basic spatial unit (BSU) is a geometrical construct representing a small spatial area. (para. 3.72)

Benefits are the goods and services that are ultimately used and enjoyed by people and society. (para. 2.15)

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 of ecosystems. (Convention on Biological Diversity, article 2, entitled "Use of Terms")

Biome is "a biotic community finding its expression at large geographic scales, shaped by climatic factors and characterised by physiognomy and functional aspects, rather than by species or life-form composition." (Mucina, 2019). (para. 3.62)

C

Catastrophic losses are reductions in assets due to catastrophic and exceptional events. (SEEA Central Framework, para. 5.49)

Cultural services[174] are the experiential and intangible services related to the perceived or actual qualities of ecosystems whose existence and functioning contributes to a range of cultural benefits. (para. 6.51)

D

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, para. 5.76)

Discount rate is a rate of interest used to adjust the value of a stream of future flows of revenue, costs or income to account for time preferences and attitudes to risk. (SEEA Central Framework, para. 5.145)

E

Economic owner is the institutional unit entitled to claim the benefits associated with the use of an asset in the course of an economic activity by virtue of accepting the associated risks. (2008 SNA, para. 10.5)

[174] The label "cultural services" is a pragmatic choice and reflects its longstanding use in the ecosystem services measurement community. It is not implied that culture itself is a service, rather it is a summary label intended to capture the variety of ways in which people connect to, and identify with, nature and the variety of motivations for these connections.

Ecosystem is "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (Convention on Biological Diversity, article 2, entitled "Use of terms").

Ecosystem accounting area (EAA) is the geographical territory for which an ecosystem account is compiled. (para. 2.12)

Ecosystem assets (EAs) are contiguous spaces of a specific ecosystem type characterized by a distinct set of biotic and abiotic components and their interactions. (para. 2.11)

Ecosystem asset life is the time over which an ecosystem asset is expected to generate ecosystem services. (para. 10.72)

Ecosystem capability concerns an ecosystem's ability to generate an ecosystem service under current conditions and type of use, irrespective of the potential impacts of increasing the supply of that service on the supply of other ecosystem services. (para. 6.150)

Ecosystem capacity is the ability of an ecosystem to generate an ecosystem service under current ecosystem condition, management and uses, at the highest yield or use level that does not negatively affect the future supply of the same or other ecosystem services from that ecosystem. (para. 6.141)

Ecosystem characteristics are the system properties of the ecosystem and its major abiotic and biotic components (water, soil, topography, vegetation, biomass, habitat and species) with examples of characteristics including vegetation type, water quality and soil type. (para. 5.28)

Ecosystem condition is the quality of an ecosystem measured in terms of its abiotic and biotic characteristics. (para. 2.13)

Ecosystem condition indicators are rescaled versions of ecosystem condition variables. (para. 5.60)

Ecosystem condition indices (and sub-indices) are composite indicators that are aggregated from the combination of individual ecosystem condition indicators recorded in the ecosystem condition indicator account. (para. 5.81)

Ecosystem condition typology (ECT) is a hierarchical typology for organizing data on ecosystem condition characteristics. (para. 5.30)

Ecosystem condition variables are quantitative metrics describing individual characteristics of an ecosystem asset. (para. 5.41)

Ecosystem conversions refer to situations in which, for a given location, there is a change in ecosystem type involving a distinct and persistent change in the ecological structure, composition and function which, in turn, is reflected in the supply of a different set of ecosystem services. (para. 4.23)

Ecosystem degradation is the decrease in the value of an ecosystem asset over an accounting period that is associated with a decline in the condition of an ecosystem asset during that accounting period. (para. 10.21)

Ecosystem disservices arise in contexts in which the outcomes of interactions between economic units and ecosystem assets are negative from the perspective of the economic units. (para. 6.75)

Ecosystem enhancement is the increase in the value of an ecosystem asset over an accounting period that is associated with an improvement in the condition of the ecosystem asset during that accounting period. (para. 10.15)

Ecosystem extent is the size of an ecosystem asset. (para. 2.13)

Ecosystem functional groups (EFG), third level of the IUCN GET classification. They are functionally distinctive groups of ecosystems within a biome and are defined in a manner consistent with the CBD definition of ecosystems. (para. 3.64)

Ecosystem integrity is defined as the ecosystem's capacity to maintain its characteristic composition, structure, functioning and self-organisation over time within a natural range of variability (Pimentel & Edwards, 2000). (para. 5.10)

Ecosystem service measurement baseline is the level of service supply with which a regulating or maintenance service provided by an ecosystem is compared in order to quantify the service. (para. 7.71)

Ecosystem services are the contributions of ecosystems to the benefits that are used in economic and other human activity. (para. 2.14)

Ecosystem services mapping is the discipline of allocating the supply and use of ecosystem services to locations. (para. 7.66)

Ecosystem type (ET) reflects a distinct set of abiotic and biotic components and their interactions. (para. 2.11)

Environmental assets are the naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity. (SEEA Central Framework, para. 2.17)

Environmental pressure is a human induced process that alters the condition of ecosystems (Maes et al., 2018).

Exchange values are the values at which goods, services, labour or assets are in fact exchanged or else could be exchanged for cash. (2008 SNA, para. 3.118)

Exclusive economic zone (EEZ) of a country is the area extending up to 200 nautical miles from a country's normal baselines as defined in the United Nations Convention on the Law of the Sea of 10 December 1982. (SEEA Central Framework, para. 5.248 and related footnote)

Externalities are impacts that "arise when the actions of an individual, firm or community affect the welfare of other individuals, firms or communities [and the] agent responsible for the action does not take full account of the effect" (Markandya et al., 2001). (para. 12.14)

F

Final ecosystem services are those ecosystem services in which the user of the service is an economic unit – i.e., business, government or household. (para. 6.24)

G

Gross ecosystem product (GEP) is equal to the sum of all final ecosystem services at their exchange value supplied by all ecosystem types located within an ecosystem accounting area over an accounting period less the net imports of intermediate services. (para. 9.18)

I

Intermediate services are those ecosystem services in which the user of the ecosystem services is an ecosystem asset and where there is a connection to the supply of final ecosystem services. (para. 6.26)

IUCN Global Ecosystem Typology (IUCN GET) is a global typological framework that applies an ecosystem process-based approach to ecosystem classification for all ecosystems around the world. The SEEA ecosystem type reference classification reflects the IUCN GET. (para. 3.58)

L

Landscapes (including those involving freshwater) are defined for accounting purposes as groups of contiguous, interconnected ecosystem assets representing a range of different ecosystem types.

Land cover refers to the observed physical and biological cover of the Earth's surface and includes natural vegetation and abiotic (non-living) surfaces. (SEEA Central Framework, para. 5.257)

Land management is the process of managing the use and development of land resources. The degree that areas of land and water are managed by humans may differ from more intensively managed (e.g., build up areas, cropland) to less intensively managed (e.g., polar regions, oceans). (para. 3.83)

Land ownership is a key characteristic that provides a direct link between ecosystems, their management and economic statistics. (para. 3.84)

Land use reflects both (a) the activities undertaken and (b) the institutional arrangements put in place for a given area for the purposes of economic production, or the maintenance and restoration of environmental functions. (SEEA Central Framework, para. 5.246)

Legal owner is the institutional unit entitled in law and sustainable under the law to claim the benefits associated with the entities. (2008 SNA, para. 10.5)

M

Managed expansion represents an increase in the area of an ecosystem type due to direct human activity in the ecosystem, including the unplanned effects of such activity. (para. 4.15)

Managed reduction represents a decrease in the area of an ecosystem type due to direct human activity in the ecosystem, including the unplanned effects of such activity, or cases where the activity may be illegal. (para. 4.15)

Market prices are defined as amounts of money that willing buyers pay to acquire something from willing sellers. (2008 SNA, para. 3.119)

N

Natural ecosystems are predominantly influenced by natural ecological processes characterised by a stable ecological state maintaining ecosystem integrity; ecosystem condition ranges within its natural variability. (Table 5.7)

Natural inputs are all physical inputs that are moved from their location in the environment as part of economic production processes or are directly used in production. (SEEA Central Framework, para. 3.45)

Natural resources include all natural biological resources (including timber and aquatic resources), mineral and energy resources, soil resources and water resources. (SEEA Central Framework, paras. 2.101 and 5.18)

Natural resource residuals are natural resource inputs that do not subsequently become incorporated into production processes and, instead, immediately return to the environment. (SEEA Central Framework, para. 3.98)

Net present value (NPV) is the value of an asset determined by estimating the stream of income expected to be earned in the future and then discounting the future income back to the present accounting period. (SEEA Central Framework, para. 5.110)

Non-SNA benefits are goods and services that are not included in the production boundary of the SNA. (para. 6.18)

Non-use values are values that people assign to ecosystems irrespective of whether they use or intend to use the ecosystems. (para. 6.70)

O

Other changes in the volume of ecosystem assets are changes in the value of an ecosystem asset, other than (i) those due to ecosystem enhancement, ecosystem degradation and ecosystem conversion, and (ii) those that are solely the result of changes in unit prices of ecosystem services. (para. 10.36)

P

Potential supply concerns an ecosystem's ability to generate an ecosystem service without the constraint of considering current patterns of use but still requiring that the condition of the ecosystem is unaffected. (para 6.150)

Provisioning services are those ecosystem services representing the contributions to benefits that are extracted or harvested from ecosystems. (para. 6.51)

R

Realm is a major component of the biosphere that differs fundamentally in ecosystem organization and function. (para. 3.61)

Reference condition is the condition against which past, present and future ecosystem condition is compared to in order to measure relative change over time. (para. 5.69)

Reference level is the value of a variable at the reference condition, against which it is meaningful to compare past, present or future measured values of the variable. (para. 5.65)

Regulating and maintenance services are those ecosystem services resulting from the ability of ecosystems to regulate biological processes and to influence climate, hydrological and biochemical cycles, and thereby maintain environmental conditions beneficial to individuals and society. (para. 6.51)

Residuals are flows of solid, liquid and gaseous materials, and energy that are discarded, discharged or emitted by establishments and households through processes of production, consumption or accumulation. (SEEA Central Framework, para. 3.73)

Resource rent is the economic rent that accrues in relation to environmental assets, including natural resources. (SEEA Central Framework, para. 5.114)

Revaluations are changes in the value of ecosystem assets over an accounting period that are due solely to movements in the unit prices of ecosystem services which underpin the derivation of the net present value of ecosystem assets. (para. 10.41)

S

Seascapes (including those involving freshwater) are defined for accounting purposes as groups of contiguous, interconnected ecosystem assets representing a range of different ecosystem types.

SNA benefits are goods and services that are included in the production boundary of the SNA. (para. 6.17)

Spatial functions are (i) flows related to the use of the environment as the location for transportation and movement, and for buildings and structures; and (ii) flows related to the use of the environment as a sink for pollutants and waste. (Table 6.1)

Supply and use tables are accounting tables structured to record flows of final ecosystem services between economic units and ecosystems and flows of intermediate services among ecosystems. Entries can be made in physical and monetary terms. (para. 7.5)

U

Unmanaged expansion represents an increase in area of an ecosystem type resulting from natural processes, including seeding, sprouting, suckering or layering. (para. 4.15)

Unmanaged reduction represents a decrease in area of an ecosystem type associated with natural processes. (para. 4.15)

Use values are values arising where the benefit to people is revealed through their direct, personal interaction with the environment or through indirect use. (para. 6.69)

V

Value transfers comprise a set of techniques that utilize data from specific locations to estimate monetary values in other locations (they are also known as benefit transfers). (section 9.5)

W

Welfare values are those monetary values reflecting the total benefit accruing to consumers and suppliers in the exchange of goods and services. It is commonly measured as the sum of consumer and producer surplus. (para. A12.8)

References

Agren, G. I., & Andersson, F. O. (2011). Terrestrial Ecosystem Ecology. In *Terrestrial Ecosystem Ecology: Principles and Applications*. Cambridge University Press. https://doi.org/10.1017/CBO9780511894572

Alam, M., Ivo Encomenderos, Godoy, F., Grantham, H., Honzák, M., Juhn, D., Kundu, P., Larsen, T., Portela, R., Reuter, K., Rodríguez, A. M., Schneider, C., & Wright, M. (2016). *Indicadores y Otros Métodos Usados en las Cuentas Experimentales de Ecosistemas en San Martín, Perú*. https://www.conservation.org/docs/default-source/publication-pdfs/tomo_2_final.pdf?sfvrsn=68ed216f_3

American Meteorological Society. (2020). *Glossary of Meteorology*. http://glossary.ametsoc.org/

Andreasen, J. K., O'Neill, R. V, Noss, R., & Slosser, N. C. (2001). Considerations for the development of a terrestrial index of ecological integrity. *Ecological Indicators*, *1*(1), 21–35. https://doi.org/https://doi.org/10.1016/S1470-160X(01)00007-3

Arrow, K., Dasgupta, P., Goulder, L., Mumford, K., & Oleson, K. (2012). Sustainability and the Measurement of Wealth. *Environment and Development Economics*, *17*, 317–353. https://doi.org/10.1017/S1355770X12000137

Ayres, R., van den Berrgh, J., & Gowdy, J. (2001). Strong versus Weak Sustainability. *Environmental Ethics*, *23*(2), 155–168. https://doi.org/10.5840/enviroethics200123225

Badura, T., Ferrini, S., Burton, M., Binner, A., & Bateman, I. J. (2020). Using Individualised Choice Maps to Capture the Spatial Dimensions of Value Within Choice Experiments. *Environmental and Resource Economics*, *75*(2), 297–322. https://doi.org/10.1007/s10640-019-00358-3

Badura, T., Ferrini, S., & Turner, K. (2020). *Natural Capital Accounting For Better Informed Decision Making: A Case For Complementary Accounting. Report to the European Commission.*

Bagstad, K. J., Semmens, D. J., Waage, S., & Winthrop, R. (2013). A comparative assessment of decision-support tools for ecosystem services quantification and valuation. *Ecosystem Services*, *5*, 27–39. https://doi.org/10.1016/j.ecoser.2013.07.004

Bailey, R. G. (2009). *Ecosystem Geography: From Ecoregions to Sites*. Springer Science & Business Media.

Bailey, R. G. (2014). Ecoregions. In *Ecoregions: The Ecosystem Geography of the Oceans and Continents*. Springer New York. https://doi.org/10.1007/978-1-4939-0524-9

Bailey, R. G., Scarnecchia, D. L., & Bailey, R. G. (1996). Ecosystem Geography. *Ecosystem Geography*, *49*(5), 477. https://doi.org/10.2307/4002935

Barbier, E. B. (2013). Wealth accounting, ecological capital and ecosystem services. *Environment and Development Economics*, *18*(2), 133–161. https://doi.org/10.1017/S1355770X12000551

Barton, D. N., Caparrós, A., Conner, N., Edens, B., Piaggio, M., Turpie, J., & United Nations. (2019). *Defining exchange and welfare values, articulating institutional arrangements and establishing the valuation context for ecosystem accounting. Discussion paper 5.1. Paper drafted as input into the revision of the System on Environmental-Economic Accountin*. https://seea.un.org/sites/seea.un.org/files/documents/EEA/discussion_paper_5.1_defining_values_for_erg_aug_2019.pdf

Bateman, I. J., Day, B. H., Georgiou, S., & Lake, I. (2006). The aggregation of environmental benefit values: Welfare measures, distance decay and total WTP. *Ecological Economics*, *60*(2), 450–460. https://doi.org/https://doi.org/10.1016/j.ecolecon.2006.04.003

Bateman, I. J., Harwood, A. R., Mace, G. M., Watson, R. T., Abson, D. J., Andrews, B., Binner, A., Crowe, A., Day, B. H., Dugdale, S., Fezzi, C., Foden, J., Hadley, D., Haines-Young, R., Hulme, M., Kontoleon, A., Lovett, A. A., Munday, P., Pascual, U., … Termansen, M. (2013). Bringing Ecosystem Services into Economic Decision-Making: Land Use in the United Kingdom. *Science*, *341*(6141), 45 LP – 50. https://doi.org/10.1126/science.1234379

Bateman, I. J., Jones, A. P., Nishikawa, N., & Brouwer, R. (2000). Benefits transfer in theory and practice: A review and some new studies. *CSERGE and School of Environmental Sciences,* *University of East Anglia*. https://www.researchgate.net/profile/Andy_Jones3/publication/265191995_BENEFITS_TRANSFER_IN_THEORY_AND_PRACTICE_A_REVIEW_AND_SOME_NEW_STUDIES/links/54881d2a0cf289302e2efdba.pdf

Baumgärtner, S. (2007). The Insurance Value of Biodiversity in the Provision of Ecosystem Services. *Natural Resource Modeling*, *20*, 87–127. https://doi.org/10.1111/j.1939-7445.2007.tb00202.x

Baumgärtner, S., Klein, A. M., Thiel, D., & Winkler, K. (2015). Ramsey Discounting of Ecosystem Services. *Environmental and Resource Economics*, *61*(2), 273–296. https://doi.org/10.1007/s10640-014-9792-x

Bland, L. M., Watermeyer, K. E., Keith, D. A., Nicholson, E., Regan, T. J., & Shannon, L. J. (2018). Assessing risks to marine ecosystems with indicators, ecosystem models and experts. *Biological Conservation*, *227*, 19–28. https://doi.org/10.1016/j.biocon.2018.08.019

Bogaart, P., Polman, E., Verweij, R., & Swaay, C. van. (2020). *The SEEA-EEA experimental biodiversity account for the Netherlands*. https://www.cbs.nl/en-gb/background/2020/41/seea-eea-biodiversity-account-2006-2013

Bolt, K., Cranston, G., Maddox, T., McCarthy, D., Vause, J., & Vira, B. (2016). *Biodiversity at the heart of accounting for natural capital: the key to credibility*.

Bordt, M., & Saner, M. (2019). Which ecosystems provide which services? A meta-analysis of nine selected ecosystem services assessments. *One Ecosystem*, *4*. https://doi.org/10.3897/oneeco.4.e31420

Boyd, J., & Banzhaf, S. (2007). What are ecosystem services? The need for standardized environmental accounting units. *Ecological Economics*, *63*(2–3), 616–626. https://doi.org/10.1016/j.ecolecon.2007.01.002

Boyle, K. J., Kuminoff, N. V, Parmeter, C. F., & Pope, J. C. (2010). The Benefit-Transfer Challenges. *Annual Review of Resource Economics*, *2*(1), 161–182. https://doi.org/10.1146/annurev.resource.012809.103933

Boyle, K. J., & Wooldridge, J. M. (2018). Understanding Error Structures and Exploiting Panel Data in Meta-analytic Benefit Transfers. *Environmental and Resource Economics*, *69*(3), 609–635. https://doi.org/10.1007/s10640-017-0211-y

Brink, B. ten. (2007). *The natural capital index framework. Contribution to Beyond GDP „Virtual Indicator Expo", Brussels, Nov. 2007*. https://ec.europa.eu/environment/beyond_gdp/download/factsheets/bgdp-ve-nci.pdf

Buckland, S. T., Magurran, A. E., Green, R. E., & Fewster, R. M. (2005). Monitoring change in biodiversity through composite indices. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *360*(1454), 243–254. https://doi.org/10.1098/rstb.2004.1589

Burgass, M., Halpern, B., Nicholson, E., & Milner-Gulland, E. (2017). Navigating uncertainty in environmental composite indicators. *Ecological Indicators*, *75*, 268–278. https://doi.org/10.1016/j.ecolind.2016.12.034

Burkhard, B., Kandziora, M., Hou, Y., & Müller, F. (2014). Ecosystem service potentials, flows and demands-concepts for spatial localisation, indication and quantification. *Landscape Online*, *34*(0 SE-Research Article), 1–32. https://doi.org/10.3097/LO.201434

Burkhard, B., & Maes, J. (Eds.). (2017). *Mapping Ecosystem Services*. Pensoft Publishers. https://doi.org/10.3897/ab.e12837

Cadotte, M. W., Carscadden, K., & Mirotchnick, N. (2011). Beyond species: functional diversity and the maintenance of ecological processes and services. *Journal of Applied Ecology*, *48*(5), 1079–1087. https://doi.org/10.1111/j.1365-2664.2011.02048.x

Caparrós, A., Campos, P., & Montero, G. (2003). An Operative Framework for Total Hicksian Income Measurement: Application to a Multiple Use Forest. *Environmental and Resource Economics*, *26*(2), 173–198. https://doi.org/10.1023/a:1026306832349

Caparrós, A., Oviedo, J. L., Álvarez, A., & Campos, P. (2017). Simulated exchange values and

ecosystem accounting: Theory and application to free access recreation. *Ecological Economics*, *139*, 140–149. https://doi.org/10.1016/j.ecolecon.2017.04.011
Castaneda Sanchez, J. P., Obst, C., Varela, E., Barrios, J. M., & Narloch, U. G. (2017). *Forest Accounting Sourcebook : Policy Applications and Basic Compilation*. http://documents.worldbank.org/curated/en/772391580132234164/Forest-Accounting-Sourcebook-Policy-Applications-and-Basic-Compilation
Cerilli, S., La Notte, A., Pisani, D., Vallecillo, S., & Tubiello, F. N. (2020). A sustainability scoreboard for crop provision in Europe. *Ecosystem Services*, *46*, 101194. https://doi.org/10.1016/j.ecoser.2020.101194
Cernansky, R. (2017). Biodiversity moves beyond counting species. *Nature*, *546*(7656), 22–24. https://doi.org/10.1038/546022a
Corona, J., Doley, T., Griffiths, C., Massey, M., Moore, C., Muela, S., Rashleigh, B., Wheeler, W., Whitlock, S. D., & Hewitt, J. (2020). An Integrated Assessment Model for Valuing Water Quality Changes in the United States. *Land Economics* , *96*(4), 478–492. https://doi.org/10.3368/wple.96.4.478
Costanza, R. (1992). Toward an Operational Definition of Ecosystem Health. In R. Costanza, B. G. Norton, & B. D. Haskell (Eds.), *Ecosystem Health. New Goals for Environmental Management* (pp. 239–256). Island Press.
Costanza, R. (2008). Ecosystem services: Multiple classification systems are needed. *Biological Conservation*, *141*(2), 350–352. https://doi.org/https://doi.org/10.1016/j.biocon.2007.12.020
Council, N. R. (1999). *Nature's Numbers* (W. D. Nordhaus & E. C. Kokkelenberg (Eds.)). National Academies Press. https://doi.org/10.17226/6374
Cropper, M. L., & Khanna, S. (2014). How Should the World Bank Estimate Air Pollution Damages? *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2537875
Czúcz, B., Keith, H., Driver, A., Jackson, B., Nicholson, E., & Maes, J. (2021a). A common typology for ecosystem characteristics and ecosystem condition variables. *One Ecosystem*, *6*, e58218. https://doi.org/10.3897/oneeco.6.e58218
Czúcz, B., Keith, H., Maes, J., Driver, A., Jackson, B., Nicholson, E., Kiss, M., & Obst, C. (2021b). Selection criteria for ecosystem condition indicators. *Ecological Indicators*, *133*.
Czúcz, B., Molnár, Z., Horváth, F., Nagy, G. G., Botta-Dukát, Z., & Török, K. (2012). Using the natural capital index framework as a scalable aggregation methodology for regional biodiversity indicators. *Journal for Nature Conservation*, *20*(3), 144–152. https://doi.org/10.1016/j.jnc.2011.11.002
Dasgupta, P. (2009). The Welfare Economic Theory of Green National Accounts. *Environmental and Resource Economics*, *42*(1), 3–38. https://doi.org/10.1007/s10640-008-9223-y
de Groot, R., Alkemade, R., Braat, L., Hein, L., & Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological Complexity*, *7*(3), 260–272. https://doi.org/10.1016/j.ecocom.2009.10.006
Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J. R., Arico, S., Báldi, A., Bartuska, A., Baste, I. A., Bilgin, A., Brondizio, E., Chan, K. M., Figueroa, V. E., Duraiappah, A., Fischer, M., Hill, R., … Zlatanova, D. (2015). The IPBES Conceptual Framework — connecting nature and people. *Current Opinion in Environmental Sustainability*, *14*, 1–16. https://doi.org/10.1016/j.cosust.2014.11.002
Dietzenbacher, E., & Los, B. (1998). Structural Decomposition Techniques: Sense and Sensitivity. *Economic Systems Research*, *10*(4), 307–324. https://doi.org/10.1080/09535319800000023
Dimitrakopoulos, P. G., & Troumbis, A. Y. (2019). Biotopes. In *Encyclopedia of Ecology* (pp. 359–365). Elsevier. https://doi.org/10.1016/B978-0-12-409548-9.10923-6
Dooley, K., Stabinsky, D., Stone, K., Sharma, S., Anderson, T., Gurian-Sherman, D., & Riggs, P. (2018). *Missing Pathways to 1.5°C: The role of the land sector in ambitious climate action*. https://static1.squarespace.com/static/5b22a4b170e802e32273e68c/t/5bef947f4fa51adec11bfa69/1542427787745/MissingPathwaysCLARAreport_2018r2.pdf

Edens, B., & Hein, L. (2013). Towards a consistent approach for ecosystem accounting. *Ecological Economics*, *90*, 41–52. https://doi.org/10.1016/j.ecolecon.2013.03.003
eftec. (2015). *Developing Corporate Natural Capital Accounts. Guidelines for the Natural Capital Committee.* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/516971/ncc-research-cnca-guidelines.pdf
Ellis, E. C. (2011). Anthropogenic transformation of the terrestrial biosphere. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *369*(1938), 1010–1035. https://doi.org/10.1098/rsta.2010.0331
Ellis, E. C., Klein Goldewijk, K., Siebert, S., Lightman, D., & Ramankutty, N. (2010). Anthropogenic transformation of the biomes, 1700 to 2000. *Global Ecology and Biogeography*, *19*(5), no-no. https://doi.org/10.1111/j.1466-8238.2010.00540.x
European Commission. (2003). *Common implementation strategy for the water framework directive (2000/60/EC). Guidance Document No 10. Rivers and Lakes – Typology, Reference Conditions and Classification Systems. Produced by Working Group 2.3 – REFCOND*. http://www.wrrl-info.de/docs/Guidance_doc_10_REFCOND_klein.pdf
European Commission. (2016). *Mapping and Assessment of Ecosystems and their Services. Mapping and assessing the condition of Europe's ecosystems: Progress and challenges. 3rd Report.* https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/3rdMAESReport_Condition.pdf
European Environment Agency. (1999). *Environmental indicators: Typology and overview. Technical report No 25/1999*. https://www.eea.europa.eu/publications/TEC25
Faith, D. P. (2018). *How we should value biodiversity in the Anthropocene*. https://royalsocietypublishing.org/action/downloadSupplement?doi=10.1098%2Frspb.2016.2094&file=eletter.pdf
FAO. (2019). *The State of the World's Biodiversity for Food and Agriculture*. http://www.fao.org/3/CA3129EN/CA3129EN.pdf
FAO, & UNSD. (2020). *System of Environmental-Economic Accounting for Agriculture Forestry and Fisheries (SEEA AFF)*. https://doi.org/10.4060/ca7735en
Fenichel, E. P., & Abbott, J. K. (2014). Natural Capital: From Metaphor to Measurement. *Journal of the Association of Environmental and Resource Economists*, *1*(1/2), 1–27. https://doi.org/10.1086/676034
Fenichel, E. P., Abbott, J. K., & Yun, S. Do. (2018). The nature of natural capital and ecosystem income. In *Handbook of Environmental Economics* (Vol. 4). Elsevier B.V. https://doi.org/10.1016/bs.hesenv.2018.02.002
Ferrier, S., Ninan, K. N., Leadley, P., Alkemade, R., Acosta, L., Akcakaya, H. R., Brotons, L., Cheung, W., Christensen, V., Harhash, K. A., Kabubo-Mariara, J., Lundquist, C., Obersteiner, M., Pereira, H., Peterson, G., Pichs-Madruga, R., Ravindranath, N., Rondinini, C., & Wintle, B. (2016). *IPBES (2016): Summary for policymakers of the methodological assessment of scenarios and models of biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* https://doi.org/https://doi.org/10.5281/zenodo.3235428
Fulton, E. A., Smith, A. D. M., & Punt, A. E. (2005). Which ecological indicators can robustly detect effects of fishing? *ICES Journal of Marine Science*, *62*(3), 540–551. https://doi.org/10.1016/j.icesjms.2004.12.012
Gibbons, P., Briggs, S. V., Ayers, D. A., Doyle, S., Seddon, J., McElhinny, C., Jones, N., Sims, R., & Doody, J. S. (2008). Rapidly quantifying reference conditions in modified landscapes. *Biological Conservation*, *141*(10), 2483–2493. https://doi.org/10.1016/j.biocon.2008.07.009
Glenk, K., Johnston, R. J., Meyerhoff, J., & Sagebiel, J. (2020). Spatial Dimensions of Stated Preference Valuation in Environmental and Resource Economics: Methods, Trends and Challenges. *Environmental and Resource Economics*, *75*(2), 215–242. https://doi.org/10.1007/s10640-018-00311-w

Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, *86*, 235–245. https://doi.org/10.1016/j.ecolecon.2012.08.019

Grenier, M., Lantz, N., Soulard, F., & Wang, J. (2020). The use of combined Landsat and Radarsat data for urban ecosystem accounting in Canada. *Statistical Journal of the IAOS*, *36*, 823–839. https://doi.org/10.3233/SJI-200663

Haines-Young, R., & Potschin-Young, M. (2010). The links between biodiversity, ecosystem service and human well-being. In *Ecosystem Ecology: A New Synthesis* (pp. 110–139). https://doi.org/10.1017/CBO9780511750458.007

Haines-Young, R., & Potschin, M. (2012). *CICES Version 4 : Response to Consultation*. https://cices.eu/content/uploads/sites/8/2012/09/CICES-V4_Final_26092012.pdf

Harberger, A. C. (1971). Three basic postulates for applied welfare economics: an interpretive essay. *Journal of Economic Literature*, *9*(3), 785–797. https://doi.org/10.2307/2720975

Harrison, A. (1993). Natural Assets and National Accounting. In E. Lutz (Ed.), *Toward improved accounting for the environment*. The World Bank. http://documents.worldbank.org/curated/en/364841468739232622/Toward-improved-accounting-for-the-environment

Harrison, P. A., Berry, P., Simpson, G., Haslett, J. R., Blicharska, M., Bucur, M., Dunford, R., Egoh, B. N., Garcia-Llorente, M., Geamănă, N., Geertsema, W., Lommelen, E., Meiresonne, L., & Turkelboom, F. (2014). Linkages between biodiversity attributes and ecosystem services: A systematic review. *Ecosystem Services*, *9*, 191–203. https://doi.org/https://doi.org/10.1016/j.ecoser.2014.05.006

Hartwick, J. M., & Olewiler, N. D. (1998). *The Economics of Natural Resource Use* (2nd editio). Pearson.

Hein, L., Bagstad, K. J., Edens, B., Obst, C., de Jong, R., & Lesschen, J. P. (2016). Defining Ecosystem Assets for Natural Capital Accounting. *PLOS ONE*, *11*(11), e0164460. https://doi.org/10.1371/journal.pone.0164460

Hicks, J. R. (1975). The Scope and Status of Welfare Economics. *Oxford Economic Papers*, *27*(3), 307–326. https://doi.org/10.1093/oxfordjournals.oep.a041321

Hiers, J., Mitchell, R., Barnett, A., Walters, J., Mack, M., Williams, B., & Sutter, R. (2012). The Dynamic Reference Concept: Measuring Restoration Success in a Rapidly Changing No-Analogue Future. *Ecological Restoration*, *30*, 27–36. https://doi.org/10.3368/er.30.1.27

Holling, C. S. (1973). Resilience and Stability of Ecological Systems. *Annual Review of Ecology and Systematics*, *4*(1), 1–23. https://doi.org/10.1146/annurev.es.04.110173.000245

Jakobsson, S., Töpper, J. P., Evju, M., Framstad, E., Lyngstad, A., Pedersen, B., Sickel, H., Sverdrup-Thygeson, A., Vandvik, V., Velle, L. G., Aarrestad, P. A., & Nybø, S. (2020). Setting reference levels and limits for good ecological condition in terrestrial ecosystems – Insights from a case study based on the IBECA approach. *Ecological Indicators*, *116*, 106492. https://doi.org/10.1016/j.ecolind.2020.106492

Johnston, R. J., Besedin, E. Y., & Holland, B. M. (2019). Modeling Distance Decay Within Valuation Meta-Analysis. *Environmental and Resource Economics*, *72*(3), 657–690. https://doi.org/10.1007/s10640-018-0218-z

Johnston, R. J., Besedin, E. Y., & Stapler, R. (2017). Enhanced Geospatial Validity for Meta-analysis and Environmental Benefit Transfer: An Application to Water Quality Improvements. *Environmental and Resource Economics*, *68*(2), 343–375. https://doi.org/10.1007/s10640-016-0021-7

Johnston, R. J., Boyle, K. J., Adamowicz, W., Bennett, J., Brouwer, R., Cameron, T. A., Hanemann, W. M., Hanley, N., Ryan, M., Scarpa, R., Tourangeau, R., & Vossler, C. A. (2017). Contemporary Guidance for Stated Preference Studies. *Journal of the Association of Environmental and Resource Economists*, *4*(2), 319–405. https://doi.org/10.1086/691697

Johnston, R. J., Boyle, K. J., Loureiro, M., Navrud, S., & Rolfe, J. (n.d.). Guidance to Enhance the Validity and Credibility of Environmental Benefit Transfers (forthcoming). *Environmental and*

Resource Economics.
Johnston, R. J., Boyle, K. J., Loureiro, M., Navrud, S., & Rolfe, J. (2020). Targeted Guidelines to Enhance the Validity and Credibility of Environmental Benefit Transfers. *Submitted as Part of the Thematic Session, "Benefit Transfer for Natural Capital Accounting," Proposed for the 25th EAERE Annual Conference, Berlin, Germany., January 28, 2020*.
Johnston, R. J., Rolfe, J., Rosenberger, R. S., & Brouwer, R. (2015). *Benefit Transfer of Environmental and Resource Values* (R. J. Johnston, J. Rolfe, R. S. Rosenberger, & R. Brouwer (Eds.)). Springer Netherlands. https://doi.org/10.1007/978-94-017-9930-0
Johnston, R. J., Rolfe, J., & Zawojska, E. (2018). Benefit Transfer of Environmental and Resource Values: Progress, Prospects and Challenges. *International Review of Environmental and Resource Economics*, *12*(2–3), 177–266. https://doi.org/10.1561/101.00000102
Johnston, R. J., & Rosenberger, R. S. (2010). METHODS, TRENDS AND CONTROVERSIES IN CONTEMPORARY BENEFIT TRANSFER. *Journal of Economic Surveys*, *24*(3), 479–510. https://doi.org/https://doi.org/10.1111/j.1467-6419.2009.00592.x
Karr, J. (1981). Assesment of Biotic Integrity Using Fish Communities. *Fisheries*, *6*, 21–27. https://doi.org/10.1577/1548-8446(1981)006<0021:AOBIUF>2.0.CO;2
Karr, J. (1993). Defining and assessing ecological integrity: Beyond water quality. *Environmental Toxicology and Chemistry*, *12*, 1521–1531. https://doi.org/10.1002/etc.5620120902
Keddy, P. A. (1992). Assembly and response rules: two goals for predictive community ecology. *Journal of Vegetation Science*, *3*(2), 157–164. https://doi.org/10.2307/3235676
Keddy, P. A. (2010). *Wetland Ecology: Principles and Conservation*. Cambridge University Press. https://books.google.com/books?id=eVeaSqFy2VgC
Keith, D. A., Ferrer-Paris, J. R., Nicholson, E., & Kingsford, R. (2020). *IUCN Global Ecosystem Typology 2.0: descriptive profiles for biomes and ecosystem functional groups* (D. A. Keith, J. R. Ferrer-Paris, E. Nicholson, & R. T. Kingsford (Eds.)). IUCN, International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2020.13.en
Keith, D. A., Rodríguez, J. P., Rodríguez-Clark, K. M., Nicholson, E., Aapala, K., Alonso, A., Asmussen, M., Bachman, S., Basset, A., Barrow, E., Benson, J. S., Bishop, M. J., Bonifacio, R., Brooks, T. M., Burgman, M. A., Comer, P., Comín, F. A., Essl, F., Faber-Langendoen, D., … Zambrano-Martínez, S. (2013). Scientific Foundations for an IUCN Red List of Ecosystems. *PLOS ONE*, *8*(5), e62111. https://doi.org/10.1371/journal.pone.0062111
Keith, H., Czúcz, B., Jackson, B., Driver, A., Nicholson, E., & Maes, J. (2020). A conceptual framework and practical structure for implementing ecosystem condition accounts. *One Ecosystem*, *5*, e58216. https://doi.org/10.3897/oneeco.5.e58216
Keith, H., MACKEY, B., BERRY, S., LINDENMAYER, D., & GIBBONS, P. (2010). Estimating carbon carrying capacity in natural forest ecosystems across heterogeneous landscapes: addressing sources of error. *Global Change Biology*, *16*(11), 2971–2989. https://doi.org/https://doi.org/10.1111/j.1365-2486.2009.02146.x
Keith, H., Vardon, M., Obst, C., Young, V., Houghton, R. A., & Mackey, B. (2021). Evaluating nature-based solutions for climate mitigation and conservation requires comprehensive carbon accounting. *Science of The Total Environment*, *769*, 144341. https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.144341
Kim, H., Navarro, L., Campbell, J., Gill, M., Chaplin-Kramer, R., Ferrier, S., Balvanera, P., & Pereira, H. (n.d.). Essential Biodiversity Variables and Essential Ecosystem Services Variables for Post-2020 Policy Development and Implementation. *Forthcoming*.
Kingsford, M. J. (2018). Marine ecosystem. In *Encyclopædia Britannica*. Encyclopædia Britannica, inc. https://www.britannica.com/science/marine-ecosystem
Kopf, R. K., Finlayson, C. M., Humphries, P., Sims, N. C., & Hladyz, S. (2015). Anthropocene Baselines: Assessing Change and Managing Biodiversity in Human-Dominated Aquatic Ecosystems. *BioScience*, *65*(8), 798–811. https://doi.org/10.1093/biosci/biv092
La Notte, A., Maes, J., Dalmazzone, S., Crossman, N., Grizzetti, B., & Bidoglio, G. (2017). Physical and

monetary ecosystem service accounts for Europe: A case study for in-stream nitrogen retention. *Ecosystem Services*, *23*, 18–29. https://doi.org/https://doi.org/10.1016/j.ecoser.2016.11.002
La Notte, A., & Marques, A. (2019). Adjusted macroeconomic indicators to account for ecosystem degradation: an illustrative example. *Ecosystem Health and Sustainability*, *5*(1), 133–143. https://doi.org/10.1080/20964129.2019.1634979
La Notte, A., Vallecillo, S., Marques, A., & Maes, J. (2019). Beyond the economic boundaries to account for ecosystem services. *Ecosystem Services*, *35*, 116–129. https://doi.org/10.1016/j.ecoser.2018.12.007
Lavorel, S., McIntyre, S., Landsberg, J., & Forbes, T. D. A. (1997). Plant functional classifications: from general groups to specific groups based on response to disturbance. *Trends in Ecology & Evolution*, *12*(12), 474–478. https://doi.org/10.1016/S0169-5347(97)01219-6
Leopold, A. (1949). *A Sand County Almanac*.
Lockwood, J., & Mckinney, M. (2001). *Biotic Homogenization*. https://doi.org/10.1007/978-1-4615-1261-5
Lof, M., Schenau, S., Jong, R. de, Remme, R. P., Graveland, C., & Hein, L. (2017). *The SEEA EEA carbon account for the Netherlands*. https://www.cbs.nl/en-gb/background/2017/45/the-seea-eea-carbon-account-for-the-netherlands
Löfgren, K.-G. (2010). The Money Metrics Problem in Dynamic Welfare Analysis. In *Handbook of Environmental Accounting*. Edward Elgar Publishing. https://doi.org/10.4337/9781849805704.00007
Mace, G. M. (2019). The ecology of natural capital accounting. *Oxford Review of Economic Policy*, *35*(1), 54–67. https://doi.org/10.1093/oxrep/gry023
Mace, G. M., Hails, R. S., Cryle, P., Harlow, J., & Clarke, S. J. (2015). REVIEW: Towards a risk register for natural capital. *Journal of Applied Ecology*, *52*(3), 641–653. https://doi.org/10.1111/1365-2664.12431
Mace, G. M., Norris, K., & Fitter, A. H. (2012). Biodiversity and ecosystem services: a multilayered relationship. *Trends in Ecology & Evolution*, *27*(1), 19–26. https://doi.org/https://doi.org/10.1016/j.tree.2011.08.006
Mackey, B., DellaSala, D. A., Kormos, C., Lindenmayer, D., Kumpel, N., Zimmerman, B., Hugh, S., Young, V., Foley, S., Arsenis, K., & Watson, J. E. M. (2015). Policy Options for the World's Primary Forests in Multilateral Environmental Agreements. *Conservation Letters*, *8*(2), 139–147. https://doi.org/10.1111/conl.12120
Maes, J., Driver, A., Czúcz, B., Keith, H., Jackson, B., Nicholson, E., & Dasoo, M. (2020). A review of ecosystem condition accounts: lessons learned and options for further development. *One Ecosystem*, *5*, e53485. https://doi.org/10.3897/oneeco.5.e53485
Maes, J., Teller, A., Erhard, M., Grizzetti, B., Barredo, J. I., Paracchini, M. L., Condé, S., Somma, F., Orgiazzi, A., Jones, A., Zulian, G., Vallecilo, S., Petersen, J.-E., Doris Marquardt, Kovacevic, V., Malak, D. A., Marin, A. I., Czúcz, B., Mauri, A., … Werner, B. (2018). *Mapping and Assessment of Ecosystems and their Services: An analytical framework for ecosystem condition*. https://catalogue.biodiversity.europa.eu/uploads/document/file/1673/5th_MAES_report.pdf
Maes, J., Teller, A., Erhard, M., Liquete, C., Braat, L., Berry, P., Egoh, B., Puydarrieux, P., Fiorina, C., Santos-Martín, F., Paracchini, M. L., Keune, H., Wittmer, H., Hauck, J., Fiala, I., Verburg, P., Condé, S., Schägner, J. P., San-Miguel-Ayanz, J., & Bidoglio, G. (2013). *Mapping and assessment of ecosystems and their services: An analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020*. https://doi.org/10.2779/12398
Maes, J., Zulian, G., Thijssen, M., Castell, C., Baró, F., Ferreira, A., Melo, J., Garrett, C., David, N., Alzetta, C., Geneletti, D., Cortinovis, C., Zwierzchowska, I., Alves, F., Cruz, C., Blasi, C., Alós Ortí, M., Attorre, F., Azzella, M., & Teller, A. (2016). *Mapping and Assessment of Ecosystems and their Services: Urban ecosystems*. https://doi.org/10.2779/625242
Markandya, A., Harou, P., Bellu, L., & Cistulli, V. (2002). *Environmental Economics for Sustainable*

Growth. Edward Elgar Publishing Ltd.
Markandya, A., Mason, P., Perelet, R., & Taylor, T. (2001). *A dictionary of environmental economics*. Earthscan.
McNellie, M. J., Oliver, I., Dorrough, J., Ferrier, S., Newell, G., & Gibbons, P. (2020). Reference state and benchmark concepts for better biodiversity conservation in contemporary ecosystems. *Global Change Biology*, *26*(12), 6702–6714. https://doi.org/https://doi.org/10.1111/gcb.15383
Millennium Ecosystem Assessment. (2005). *Ecosystems and Human Well-being: Synthesis*. https://www.millenniumassessment.org/en/Synthesis.html
Moltmann, T., Turton, J., Zhang, H.-M., Nolan, G., Gouldman, C., Griesbauer, L., Willis, Z., Piniella, Á. M., Barrell, S., Andersson, E., Gallage, C., Charpentier, E., Belbeoch, M., Poli, P., Rea, A., Burger, E. F., Legler, D. M., Lumpkin, R., Meinig, C., … Zhang, Y. (2019). A Global Ocean Observing System (GOOS), Delivered Through Enhanced Collaboration Across Regions, Communities, and New Technologies . In *Frontiers in Marine Science* (Vol. 6, p. 291). https://www.frontiersin.org/article/10.3389/fmars.2019.00291
Mori, T., Ohta, S., Ishizuka, S., Konda, R., Wicaksono, A., Heriyanto, J., Hamotani, Y., Gobara, Y., Kawabata, C., Kuwashima, K., Nakayama, Y., & Hardjono, A. (2013). Soil greenhouse gas fluxes and C stocks as affected by phosphorus addition in a newly established Acacia mangium plantation in Indonesia. *Forest Ecology and Management*, *310*, 643–651. https://doi.org/https://doi.org/10.1016/j.foreco.2013.08.010
Mucina, L. (2019). Biome: evolution of a crucial ecological and biogeographical concept. *New Phytologist*, *222*(1), 97–114. https://doi.org/10.1111/nph.15609
Muller-Karger, F., Miloslavich, P., Bax, N. J., Simmons, S., Costello, M. J., Sousa Pinto, I., Canonico, G., Turner, W., Gill, M., Montes, E., Best, B. D., Pearlman, J., Halpin, P., Dunn, D., Benson, A., Martin, C. S., Weatherdon, L. V, Appeltans, W., Provoost, P., … Geller, G. N. (2018). Advancing Marine Biological Observations and Data Requirements of the Complementary Essential Ocean Variables (EOVs) and Essential Biodiversity Variables (EBVs) Frameworks. In *Frontiers in Marine Science* (Vol. 5, p. 211). https://www.frontiersin.org/article/10.3389/fmars.2018.00211
Muller, N. Z., Mendelsohn, R., & Nordhaus, W. D. (2011). Environmental Accounting for Pollution in the United States Economy. *American Economic Review*, *101*(5), 1649–1675. https://doi.org/10.1257/aer.101.5.1649
Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., Hoffman, A., & Giovannini, E. (2005). *Handbook on Constructing Composite Indicators: Methodology and User Guide* (OECD Stati). OECD Publishing. https://doi.org/https://doi.org/https://doi.org/10.1787/533411815016
Nordhaus, W. D. (2006). Principles of National Accounting For Nonmarket Accounts. In *A New Architecture for the U.S. National Accounts* (pp. 143–160). University of Chicago Press. https://doi.org/10.7208/chicago/9780226410876.003.0004
Nordhaus, W. D., & Tobin, J. (1972). *Is Growth Obsolete?* (pp. 1-80 BT-Economic Research: Retrospect and Prospe). National Bureau of Economic Research, Inc. https://econpapers.repec.org/RePEc:nbr:nberch:7620
O'Connor, S., & Kenter, J. O. (2019). Making intrinsic values work; integrating intrinsic values of the more-than-human world through the Life Framework of Values. *Sustainability Science*, *14*(5), 1247–1265. https://doi.org/10.1007/s11625-019-00715-7
O'Neill, J., Holland, A., & Light, A. (2008). *Environmental Values*. Routledge.
Obst, C., Hein, L., & Edens, B. (2016). National Accounting and the Valuation of Ecosystem Assets and Their Services. *Environmental and Resource Economics*, *64*(1), 1–23. https://doi.org/10.1007/s10640-015-9921-1
OECD. (2008). *Towards Measuring the volume of health and education services* (Working Party on National Accounts (Ed.)).
OECD. (2014). *The Cost of Air Pollution*. OECD. https://doi.org/10.1787/9789264210448-en
OECD. (2018). *Cost-Benefit Analysis and the Environment*. OECD. https://doi.org/10.1787/9789264085169-en

OECD, International Monetary Fund, International Labour Organisation, & Interstate Statistical Committee of the Commonwealth of Independent States. (2002). *Measuring the Non-Observed Economy - A Handbook*. https://www.oecd.org/sdd/na/1963116.pdf

Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., D'amico, J. A., Itoua, I., Strand, H. E., Morrison, J. C., Loucks, C. J., Allnutt, T. F., Ricketts, T. H., Kura, Y., Lamoreux, J. F., Wettengel, W. W., Hedao, P., & Kassem, K. R. (2001). Terrestrial Ecoregions of the World: A New Map of Life on Earth: A new global map of terrestrial ecoregions provides an innovative tool for conserving biodiversity. *BioScience*, *51*(11), 933–938. https://doi.org/10.1641/0006-3568(2001)051[0933:TEOTWA]2.0.CO;2

Ostrom, E. (2010). Beyond Markets and States: Polycentric Governance of Complex Economic Systems. *American Economic Review*, *100*(3), 641–672. https://doi.org/10.1257/aer.100.3.641

Ouyang, Z., Song, C., Zheng, H., Polasky, S., Xiao, Y., Bateman, I. J., Liu, J., Ruckelshaus, M., Shi, F., Xiao, Y., Xu, W., Zou, Z., & Daily, G. (2020). Using gross ecosystem product (GEP) to value nature in decision making. *Proceedings of the National Academy of Sciences*, *117*(25), 14593 LP – 14601. https://doi.org/10.1073/pnas.1911439117

Palmer, M. A., & Febria, C. M. (2012). The Heartbeat of Ecosystems. *Science*, *336*(6087), 1393–1394. https://doi.org/10.1126/science.1223250

Paracchini, M. L., Pacini, C., Jones, M. L. M., & Pérez-Soba, M. (2011). An aggregation framework to link indicators associated with multifunctional land use to the stakeholder evaluation of policy options. *Ecological Indicators*, *11*(1), 71–80. https://doi.org/https://doi.org/10.1016/j.ecolind.2009.04.006

Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., Stenseke, M., Watson, R. T., Başak Dessane, E., Islar, M., Kelemen, E., Maris, V., Quaas, M., Subramanian, S. M., Wittmer, H., Adlan, A., Ahn, S., Al-Hafedh, Y. S., Amankwah, E., Asah, S. T., … Yagi, N. (2017). Valuing nature's contributions to people: the IPBES approach. *Current Opinion in Environmental Sustainability*, *26–27*, 7–16. https://doi.org/10.1016/j.cosust.2016.12.006

Pearce, D., & Turner, K. (1990). *Economics of Natural Resources and the Environment*. Johns Hopkins University Press.

Pérez-Harguindeguy, N., Díaz, S., Garnier, E., Lavorel, S., Poorter, H., Jaureguiberry, P., Bret-Harte, M. S., Cornwell, W. K., Craine, J. M., Gurvich, D. E., Urcelay, C., Veneklaas, E. J., Reich, P. B., Poorter, L., Wright, I. J., Ray, P., Enrico, L., Pausas, J. G., de Vos, A. C., … Cornelissen, J. H. C. (2013). New handbook for standardised measurement of plant functional traits worldwide. *Australian Journal of Botany*, *61*(3), 167. https://doi.org/10.1071/BT12225

Pettorelli, N., Schulte to Bühne, H., Tulloch, A., Dubois, G., Macinnis-Ng, C., Queirós, A. M., Keith, D. A., Wegmann, M., Schrodt, F., Stellmes, M., Sonnenschein, R., Geller, G. N., Roy, S., Somers, B., Murray, N. J., Bland, L. M., Geijzendorffer, I., Kerr, J. T., Broszeit, S., … Nicholson, E. (2018). Satellite remote sensing of ecosystem functions: opportunities, challenges and way forward. *Remote Sensing in Ecology and Conservation*, *4*(2), 71–93. https://doi.org/10.1002/rse2.59

Pimentel, D., & Edwards, C. A. (2000). Agriculture, Food, Populations, Natural Resources and Ecological Integrity. In P. Crabbé, A. Holland, L. Ryszkowski, & L. Westra (Eds.), *Implementing Ecological Integrity: Restoring Regional and Global Environmental and Human Health* (pp. 377–398). Springer Netherlands. https://doi.org/10.1007/978-94-011-5876-3_26

Polasky, S., & Segerson, K. (2009). Integrating Ecology and Economics in the Study of Ecosystem Services: Some Lessons Learned. *Annual Review of Resource Economics*, *1*(1), 409–434. https://doi.org/10.1146/annurev.resource.050708.144110

Potschin, M., & Haines-Young, R. (2016). Defining and measuring ecosystem services. In M. Potschin, R. Haines-Young, R. Fish, & R. K. Turner (Eds.), *Routledge Handbook of Ecosystem Services* (pp. 25–44). https://cices.eu/content/uploads/sites/8/2017/12/3_Potschin_RHY_2016_Defining-ES_CICES.pdf

Potschin, M., & Haines-Young, R. (2017). 2.3. From nature to society. In B. Burkhard & J. Maes (Eds.), *Mapping Ecosystem Services*. Pensoft Publishers.

Rendon, P., Erhard, M., Maes, J., & Burkhard, B. (2019). Analysis of trends in mapping and assessment of ecosystem condition in Europe. *Ecosystems and People*, *15*(1), 156–172. https://doi.org/10.1080/26395916.2019.1609581

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., … Foley, J. A. (2009). A safe operating space for humanity. *Nature*, *461*(7263), 472–475. https://doi.org/10.1038/461472a

Rowland, J. A., Lee, C. K. F., Bland, L. M., & Nicholson, E. (2020). Testing the performance of ecosystem indices for biodiversity monitoring. *Ecological Indicators*, *116*, 106453. https://doi.org/https://doi.org/10.1016/j.ecolind.2020.106453

Santos-Martín, F., Zorrilla-Miras, P., Palomo, I., Montes, C., Benayas, J., & Maes, J. (2019). Protecting nature is necessary but not sufficient for conserving ecosystem services: A comprehensive assessment along a gradient of land-use intensity in Spain. *Ecosystem Services*, *35*, 43–51. https://doi.org/10.1016/j.ecoser.2018.11.006

Sayre, R., Karagulle, D., Frye, C., Boucher, T., Wolff, N. H., Breyer, S., Wright, D., Martin, M., Butler, K., Van Graafeiland, K., Touval, J., Sotomayor, L., McGowan, J., Game, E. T., & Possingham, H. (2020). An assessment of the representation of ecosystems in global protected areas using new maps of World Climate Regions and World Ecosystems. *Global Ecology and Conservation*, *21*, e00860. https://doi.org/10.1016/j.gecco.2019.e00860

Schaafsma, M. (2015). Spatial and Geographical Aspects of Benefit Transfer. In R. J. Johnston, J. Rolfe, R. S. Rosenberger, & R. Brouwer (Eds.), *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners* (pp. 421–439). Springer Netherlands. https://doi.org/10.1007/978-94-017-9930-0_18

Schneiders, A., & Müller, F. (2017). 2 .2 A natural base for ecosystem services. In B. Burkhard & J. Maes (Eds.), *Mapping Ecosystem Services*. Pensoft Publishers.

Sen, A. (1999). *Development as Freedom*. Oxford University Press (OUP).

Smith, A. C., Harrison, P. A., Pérez Soba, M., Archaux, F., Blicharska, M., Egoh, B. N., Erős, T., Fabrega Domenech, N., György, I., Haines-Young, R., Li, S., Lommelen, E., Meiresonne, L., Miguel Ayala, L., Mononen, L., Simpson, G., Stange, E., Turkelboom, F., Uiterwijk, M., … Wyllie de Echeverria, V. (2017). How natural capital delivers ecosystem services: A typology derived from a systematic review. *Ecosystem Services*, *26*, 111–126. https://doi.org/10.1016/j.ecoser.2017.06.006

Sorrenti, S. (2017). *Non-wood forest products in international statistical systems*. FAO. https://doi.org/978-92-5-109602-4

Stamps, J. (2008). Habitat. In *Encyclopedia of Ecology* (pp. 395–397). Elsevier. https://doi.org/10.1016/B978-0-444-63768-0.00502-3

Stanley, T. D., Doucouliagos, H., Giles, M., Heckemeyer, J. H., Johnston, R. J., Laroche, P., Nelson, J. P., Paldam, M., Poot, J., Pugh, G., Rosenberger, R. S., & Rost, K. (2013). META-ANALYSIS OF ECONOMICS RESEARCH REPORTING GUIDELINES. *Journal of Economic Surveys*, *27*(2), 390–394. https://doi.org/https://doi.org/10.1111/joes.12008

Statistics South Africa. (2021a). *Natural Capital Series 3: Accounts for species: Rhinoceros, 1970 to 2017. Discussion document. Produced in collaboration with the South African National Biodiversity Institute and the Department of Environment, Forestry and Fisheries.*

Statistics South Africa. (2021b). *Natural Capital Series 4: Accounts for species: Cycads, 1970 to 2010. Discussion document. Produced in collaboration with the South African National Biodiversity Institute and the Department of Environment, Forestry and Fisheries.*

Stewart, I. D., & Oke, T. (2009). A new classification system for urban climate sites. *Bulletin of the American Meteorological Society*, *90*, 922–923.

Stoddard, J. L., Larsen, D. P., Hawkins, C. P., Johnson, R. K., & Norris, R. H. (2006). Setting Expectations For The Ecological Condition Of Streams: The Concept Of Reference Condition. *Ecological Applications*, *16*(4), 1267–1276. https://doi.org/10.1890/1051-

0761(2006)016[1267:seftec]2.0.co;2
TEEB. (2010). *The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB*. http://teebweb.org/publications/teeb-for/synthesis/
Thompson, I., Mackey, B., Mcnulty, S., & Mosseler, A. (2009). Forest Resilience, Biodiversity, and Climate Change. A Synthesis of the Biodiversity/Resilience/Stability Relationship in Forest Ecosystems. In *Technical Series no. 43*. Secretariat of the Convention on Biological Diversity, Montreal. https://www.cbd.int/doc/publications/cbd-ts-43-en.pdf
Triplett, J. (2006). *Handbook on Hedonic Indexes and Quality Adjustments in Price Indexes: Special Application to Information Technology Products*. OECD Publishing. https://doi.org/https://doi.org/https://doi.org/10.1787/9789264028159-en
Turner, K., Badura, T., & Ferrini, S. (2019). Natural capital accounting perspectives: a pragmatic way forward. *Ecosystem Health and Sustainability*, *5*(1), 237–241. https://doi.org/10.1080/20964129.2019.1682470
Turner, K., Paavola, J., Cooper, P., Farber, S., Jessamy, V., & Georgiou, S. (2003). Valuing nature: lessons learned and future research directions. *Ecological Economics*, *46*(3), 493–510. https://doi.org/10.1016/S0921-8009(03)00189-7
UN-Habitat. (n.d.). *National Sample of Cities Global Urban Observatory. A Model Approach to Monitoring and Reporting Performance of Cities at National Levels*. https://unhabitat.org/sites/default/files/download-manager-files/National_Sample_of_Cities.pdf
UNCCD. (2017). *Good Practice Guidance. SDG Indicator 15.3.1, version 1.0 .* https://www.unccd.int/sites/default/files/relevant-links/2017-10/Good Practice Guidance_SDG Indicator 15.3.1_Version 1.0.pdf
UNEP-WCMC. (2016). *Exploring approaches for constructing Species Accounts in the context of the SEEA-EEA*. https://www.unep-wcmc.org/system/comfy/cms/files/files/000/000/792/original/Exploring_Approaches_for_constructing_Species_Accounts_in_the_context_of_the_SEEA-EEA_FINAL.pdf
UNEP-WCMC, & IDEEA. (2017). *Experimental Ecosystem Accounts for Uganda*. https://www.unep-wcmc.org/system/dataset_file_fields/files/000/000/445/original/Ecosystem_Accounting_in_Uganda_Report_FINAL.pdf?1494865089
UNEP. (2014). *Guidance Manual on Valuation and Accounting of Ecosystem Services for Small Island Developing States United Nations Environment Programme* (D. Kirby, DCPI, UNEP, & E. Kemf (Eds.)). https://www.cbd.int/financial/monterreytradetech/unep-valuation-sids.pdf
UNEP. (2018). *Inclusive Wealth Report 2018*. https://www.unenvironment.org/resources/report/inclusive-wealth-report-2018
UNEP, & UNSD. (n.d.). *Policy scenario analysis using SEEA ecosystem accounts (technical report) (forthcoming)*.
United Nations. (1993). *Handbook of National Accounting. Integrated Environmental and Economic Accounting*. United Nations.
United Nations. (2012). *System of Environmental-Economic Accounting for Water (SEEA-Water)*. United Nations. https://seea.un.org/sites/seea.un.org/files/seeawaterwebversion_final_en.pdf
United Nations. (2017). *Framework for the Development of Environment Statistics (FDES 2013)*. United Nations. https://unstats.un.org/unsd/environment/FDES/FDES-2015-supporting-tools/FDES.pdf
United Nations. (2018). *System of Environmental-Economic Accounting for Energy (SEEA-Energy)*. United Nations. https://seea.un.org/sites/seea.un.org/files/documents/seea-energy_final_web.pdf
United Nations. (2019). *Technical Recommendations in support of the System of Environmental-Economic Accounting 2012—Experimental Ecosystem Accounting*. United Nations. https://seea.un.org/sites/seea.un.org/files/documents/EEA/seriesm_97e.pdf

United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, & World Bank. (2003). *Handbook of National Accounting: Integrated Environmental and Economic Accounting 2003*. United Nations. https://unstats.un.org/unsd/environment/seea2003.pdf

United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, & World Bank. (2010). System of National Accounts 2008. In *System of National Accounts 2008*. United Nations. https://doi.org/10.18356/4fa11624-en

United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, & World Bank. (2014a). *System of Environmental-Economic Accounting 2012—Central Framework*. United Nations. https://seea.un.org/sites/seea.un.org/files/seea_cf_final_en.pdf

United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, & World Bank. (2014b). *System of Environmental-Economic Accounting 2012—Experimental Ecosystem Accounting*. United Nations. https://seea.un.org/sites/seea.un.org/files/seea_eea_final_en_1.pdf

United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, & World Bank. (2017). *System of Environmental-Economic Accounting 2012—Applications and Extensions*. United Nations. https://seea.un.org/sites/seea.un.org/files/ae_final_en.pdf

UNSD. (n.d.-a). *Guidelines on Biophysical Modelling for Ecosystem Accounting (forthcoming)*.

UNSD. (n.d.-b). *Guidelines on the valuation of ecosystem services and ecosystem assets (fortcoming)*.

UNSD. (2019). *The Global Statistical Geospatial Framework*. United Nations. https://ggim.un.org/meetings/GGIM-committee/9th-Session/documents/The_GSGF.pdf

UNSD, & UNEP-WCMC. (2019). *Expert Meeting on SEEA Indicators for SDGs and Post-2020 Agenda*. https://seea.un.org/events/expert-meeting-seea-indicators-sdgs-and-post-2020-agenda

UNWTO. (2018). *Linking the TSA and the SEEA: A Technical Note*. https://webunwto.s3-eu-west-1.amazonaws.com/2019-08/tsaseeatechnote.pdf

Urban Nature Atlas Oslo. (2020). https://nina.earthengine.app/view/urban-nature-atlas

Vallecillo, S., La Notte, A., Zulian, G., Ferrini, S., & Maes, J. (2019). Ecosystem services accounts: Valuing the actual flow of nature-based recreation from ecosystems to people. *Ecological Modelling*, *392*, 196–211. https://doi.org/10.1016/j.ecolmodel.2018.09.023

Van Strien, A., Soldaat, L., & Gregory, R. (2012). Desirable mathematical properties of indicators for biodiversity change. *Computer Methods in Biomechanics and Biomedical Engineering - COMPUT METHODS BIOMECH BIOMED*, *14*, 202–208. https://doi.org/10.1016/j.ecolind.2011.07.007

Vanoli, A. (1995). Reflections On Environmental Accounting Issues. *Review of Income and Wealth*. https://doi.org/10.1111/j.1475-4991.1995.tb00104.x

Vanoli, A. (2005). *A History of National Accounting*. IOS Press. https://books.google.com/books?id=MiW7AAAAIAAJ

Vanoli, A. (2015). The Future of the SNA in a Broad Information System Perspective. *Paper Prepared for the IARIW-OECD Special Conference: "W(h)Ither the SNA?" Paris, France, April 16-17, 2015*. http://iariw.org/papers/2015/vanolikn.pdf

Villamagna, A. M., Angermeier, P. L., & Bennett, E. M. (2013). Capacity, pressure, demand, and flow: A conceptual framework for analyzing ecosystem service provision and delivery. *Ecological Complexity*, *15*, 114–121. https://doi.org/https://doi.org/10.1016/j.ecocom.2013.07.004

Walker, B. (2019). *Finding Resilience: Change and Uncertainty in Nature and Society*. CSIRO PUBLISHING. https://books.google.com/books?id=6zeLDwAAQBAJ

Weber, J.-L. (2014). *Ecosystem Natural Capital Accounts: A Quick Start Package* (Technical Series No. 77). https://www.cbd.int/doc/publications/cbd-ts-77-en.pdf

Weikard, H.-P., & Zhu, X. (2005). Discounting and Environmental Quality, When Should Dual Rates Be Used? *Economic Modelling*, *22*, 868–878. https://doi.org/10.1016/j.econmod.2005.06.004

Weitzman, M. L. (1976). On the Welfare Significance of National Product in a Dynamic Economy. *The Quarterly Journal of Economics*, *90*(1), 156. https://doi.org/10.2307/1886092

Weitzman, M. L. (1992). On Diversity. *The Quarterly Journal of Economics*, *107*(2), 363–405. https://doi.org/10.2307/2118476

Wheeler, B. (2002). Ecological Integrity: Integrating Environment, Conservation and Health. *International Journal of Epidemiology*, *31*(3), 704–705. https://doi.org/10.1093/ije/31.3.704

World Bank. (2018). *The Changing Wealth of Nations 2018*. https://www.worldbank.org/en/news/infographic/2018/01/30/the-changing-wealth-of-nations