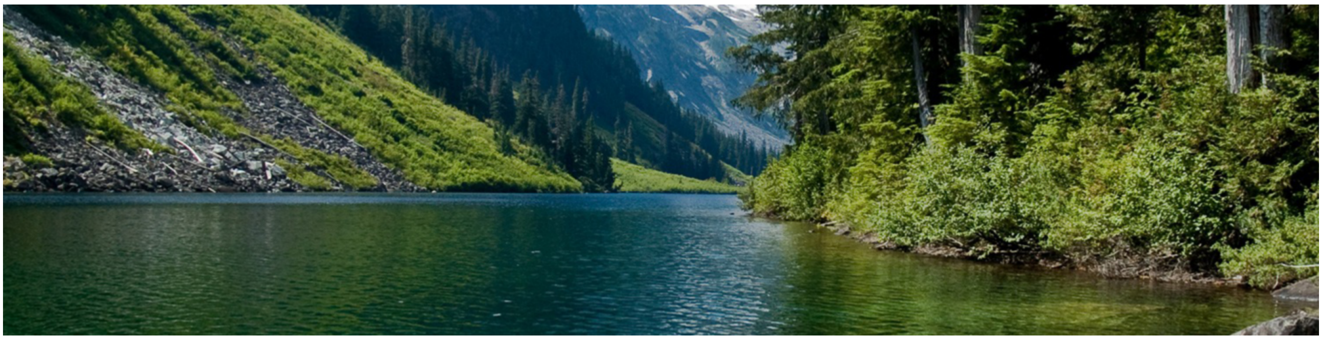


The System of Environmental-Economic Accounting (SEEA) Experimental Ecosystem Accounting

1 Introduction

Purpose of this briefing note...
The purpose of this briefing note is to describe the emerging field of ecosystem accounting and its role as a measurement framework for integrating biophysical data, tracking changes in ecosystems and linking those changes to economic and other human activity. The development of ecosystem accounting is a response to a wide range of demands for integrated information related to analytical and policy frameworks on environmental sustainability, human well being, and economic growth and development.

Policy relevance of ecosystem accounting...
Increasingly, policies are being considered in a more integrated, multi-disciplinary fashion with economic, social and environmental factors being assessed in determining appropriate policy responses. In this regard the integrated structure of the ecosystem accounts is of particular relevance. Ecosystem accounting can provide a new perspective that can be used to support decisions on the most effective use of ecosystems in support of individual and societal well-being.

Some of the key questions that may be answered with the information obtained from ecosystem accounting include:

- Which ecosystems generate which ecosystem services?
- What is the extent of the contribution of ecosystem services to economic and other human activity?
- Which ecosystems are in the best condition and which are the most degraded?
- What changes have occurred over time and what has been the impact on the generation of ecosystem services?
- What monetary values might be attached to ecosystems?

Along with the data compiled, a number of indicators (e.g. biomass index, species richness, net carbon balance etc.) can be derived from the accounting structure described in this briefing note. Potential users of the indicators and associated data include ministries of environment, natural resources, water, agriculture, health, transport, public safety, industry and finance, as well as regional and local government decision-makers. Ecosystem accounting may also support information needs and research agendas of academic institutions, non-governmental organizations, businesses and the general public. Increasingly, these stakeholders are confronted with the need to understand how ecosystems are changing and the potential impacts of those changes.

SEEA-Central Framework and SEEA-Experimental Ecosystem Accounting...
This note summarizes ecosystem accounting as described in detail in the System of Environmental-Economic Accounting 2012 (SEEA) Experimental Ecosystem Accounting. SEEA-Experimental Ecosystem Accounting presents a complementary perspective on environmental-economic accounting to that contained in the SEEA-Central Framework - the international statistical standard for environmental-economic accounting.

Both the SEEA-Central Framework and SEEA-Experimental Ecosystem Accounting use the accounting concepts, structures and principles of the System of National Accounts (SNA). Furthermore, both documents extend the accounting approach described in the SNA to account for stocks and flows in physical terms.

The SEEA-Central Framework starts from the perspective of the economy and its economic units (including households) and incorporates relevant environmental information concerning natural inputs, residual flows and associated environmental assets. In contrast, SEEA-Experimental Ecosystem Accounting starts from the perspective of ecosystems and links ecosystems to economic and other human activity. Together, the approaches provide the potential to describe in a complete manner the relationship between the environment, and economic and other human activity.

Aim of SEEA-Experimental Ecosystem Accounting...
SEEA-Experimental Ecosystem Accounting reflects a synthesis of the current knowledge in this area and can provide a starting point for the development of ecosystem accounting at national or sub-national levels. While SEEA-Experimental Ecosystem Accounting does not give precise instructions on how to compile ecosystem accounts, it represents a strong and clear convergence across the disciplines of ecology, economics and statistics on many core aspects related to the measurement of ecosystems. Thus there is a strong base on which further research and development can build.

Box 1: Case Study of ecoMarkets in Victoria, Australia

EcoMarkets is a term used to describe a range of market based approaches that the Victorian Government in Australia uses to address landscape decline and improve the health of the environment. The ecoMarkets program supports wetland, river, coastal, woodland, grassland and multiple outcome conservation auctions all across Victoria. In the last five years over 5,000 privately-owned ecosystem assets have been assessed and over AUD 20 million has been invested in works to maintain and increase the supply of ecosystem services.

To ensure that environmental investments are based on the best available data and modelling, EnSym (Environmental Systems Modelling Platform) is used by the ecoMarkets team. EnSym employs landscape modelling techniques to identify important assets and the ecosystem services they can provide. This detailed knowledge (100m by 100m grid over Victoria) of the unique aspects of any particular location in the landscape allows prediction of both the catchment and paddock scale impacts of any land management action or group of actions.

EnSym provides an integrated platform to assess changes in the stock of ecosystem assets and changes in ecosystem services being provided by those assets. This enables environmental accounts to be constructed for Victoria, providing decision makers with information required to develop effective policy and assess tradeoffs between the supply of alternative ecosystem services.

EnSym's ecosystem accounting functionality makes it possible for environmental managers to report on ecosystem asset coverage and the changes in ecosystem services that are expected to occur or that have occurred as a result of environmental investments. For example, the table below presents the expected outcomes of the West Gippsland EcoTender that result from AUD 2.5 million of landholder payments, measured using the ecoMarkets Environmental Benefits Index. The table shows there will be an 11% increase in terrestrial ecosystem services, 17% increase in river ecosystem services and 10% increase in wetland ecosystem services as a result of actions undertaken by landholders on the ecosystem assets included in EcoTender.

The ecoMarkets program will continue to trial ecosystem accounts that are consistent with international systems. It will establish clear standards for reporting on the quality and value of ecosystem assets and for recording and explaining changes over time. Importantly, this work will improve the links between environmental policy and the manner in which resources are allocated to environmental activities.

Change in Environmental Benefits Index (EBI) for participating sites in the West Gippsland EcoTender

	Terrestrial ecosystems	River ecosystems	Wetland ecosystems
Opening EBI	61,769.5	22,919.7	2,381.6
Additions to EBI-Growth in ecosystem services	7,130.1	3,837.6	241.2
Reduction in EBI-Unmanaged natural degradation	-141.4	-51.7	-0.0
Closing EBI	68,785.2	26,705.6	2,622.6
% change	11%	17%	10%

Source: Department of Sustainability and Environment, Government of Victoria, Australia

Those with a need or an interest in advancing this work are encouraged to use SEEA-Experimental Ecosystem Accounting as a starting point to engage in inter-agency discussions, to assemble a team of experts, to identify priorities, and to compile key information. It is anticipated that much progress can result from the use of common concepts and terms; collaboration on existing activities; the compilation of coherent data on ecosystems; and the development of key indicators.

2 What are ecosystems?

Definition of an ecosystem...

"Ecosystems are a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit."[1] They are systems of interdependent relationships including such processes as the flow of energy through the food chain and the cycling of carbon, water and nutrients through living and non-living components of the system. Biodiversity, the variety of genetic material, species, and ecosystems, is an important characteristic that influences and reflects ecosystem operation, condition and resilience.

Ecosystems produce the food we eat, the wood we build with and they help purify the water we drink and the air we breathe. These ecosystem services and many others are often considered "free" but measuring changes in the ability of ecosystems to provide them is an important part of understanding whether our activities are damaging the capacity of ecosystems to provide these services into the future. That is, will future generations have access to the same levels of services that we do?

What cause changes in ecosystems?

Ecosystems change as a result of natural processes and because of human actions. Key natural processes include the capture of light, energy and carbon through photosynthesis,

[1]Convention on Biological Diversity (2003)

Box 2: Ecosystem Accounting in Europe

Simplified ecosystem capital accounts are currently being implemented in Europe by the European Environment Agency in cooperation with Eurostat as one of the responses to recurrent policy demands in Europe for going "beyond GDP", accounting for ecosystems and biodiversity (TEEB) or measuring Europe's resource efficiency. Preliminary results are expected by end 2012. The objective is to measure the ecosystem resources that are accessible without degradation, the actual intensity of use of these resources, ecosystems' capability to deliver services over time, and estimate consumption of ecosystem capital and the value of particular ecosystem services.

In the simplified model, ecosystem capital analytical and reporting units at whatever scale are described with 3 accounts for biomass/carbon, water and landscapes (and similarly rivers and seascapes). In physical accounts, measurements are firstly made in basic units (tons, joules, m3 or ha) and then converted to a special composite currency-equivalent called 'Ecosystem Capability Unit'. The price of one physical unit (e.g. 1 ton of biomass) in this currency-equivalent expresses at the same time the intensity of basic resource use (below or above the maximum sustainable yield) and direct and indirect impacts on ecosystem condition (e.g. contamination, fragmentation or biodiversity loss). Loss of ecosystem capability is a measurement of ecological debts, and gains of ecological credits. To territorial debts are added the non-paid consumption of ecosystem capital embedded into international transactions. Ecological debts in Ecosystem Capability Unit' (and symmetrically credits when enhancements are verified) could be incorporated into portfolios of financial instruments.
`http://www.eea.europa.eu/publications/an-experimental-framework-for-ecosystem`

Ecosystem capital accounts are compiled on currently available data from Earth observation by satellite and in situ monitoring and on socioeconomic statistics. They cover all ecosystems types (forests, wetlands, agricultural and urban systems, sea ...) of the European Union 27 countries. The results are reported by watersheds or administrative regions, but most data are collected or disaggregated according to the European standard grid of 1 km x 1 km. This geographic detail is necessary on the one hand to detect ecosystem degradation areas within reporting regions and understand the processes at work and, on the other hand to articulate programs of national, regional or local initiative with the European level assessment. In a second step, physical accounts of ecosystem assets will be extended to the monetary estimation of consumption ecosystem capital based on remediation costs. Selected ecosystem services will be valued on an ad hoc basis.

Source: European Environment Agency

the transfer of carbon and energy through food webs, and the release of nutrients and carbon through decomposition. More widespread natural changes also occur such as recovery after major disturbances including for example fire, floods and storms.

Traditionally, ecosystems have been associated with more or less 'natural' systems, i.e. systems with, at most, a limited degree of human influence. However, human activities influence every ecosystem in the world, either through direct management (agriculture, forestry, urbanization, construction of transportation and energy corridors) or indirectly by releasing pollutants, overharvesting and introducing invasive species. For this reason, ecosystem accounting encompasses all ecosystems including managed areas such as agricultural land which are ecosystems providing particular services (e.g. crop production, carbon sequestration, supporting tourism and recreation).

Ecosystem characteristics...
Assessment of ecosystems should consider key characteristics. Key characteristics of the operation of an ecosystem are:

- its structure (e.g. the food web within the ecosystem);
- its composition, including living (e.g. flora and fauna) and non-living (e.g. soil, water) components;
- its processes (e.g. photosynthesis, decomposition); and
- its functions (e.g. recycling of nutrients in an ecosystem, primary productivity).

Key characteristics of its location are:

- its extent;
- its configuration (i.e. the way in which the various components are arranged and organised within the ecosystem);
- the landscape forms (e.g. mountain regions, coastal areas) within which the ecosystem is located; and
- the climate and associated seasonal patterns.

Ecosystem characteristics also relate strongly to biodiversity at a number of levels. In addition, ecosystems are interconnected and are subject to processes that operate over varying time scales.

3 Ecosystem accounting

Why apply accounting approach to ecosystems?
Accounting approaches are designed to integrate information on stocks, changes in stocks and related flows of services and benefits to provide a coherent picture of trends in systems. The standard economic accounts provide an integrated and coherent set of information on the economic system. Ecosystem accounting provides a picture of trends in ecosystems through integration of information on stocks

and changes in stocks of ecosystem assets, and information on flows of ecosystem services. Through application of consistent principles and conventions, ecosystem accounting provide a tool for compiling information on environmental changes and linking these changes to economic and other human activity.

Ecosystem accounting integration...

The connection between ecosystem assets and ecosystem services lies in the concept that ecosystem services are generated from ecosystem assets and that the potential for ecosystem services to be generated into the future is linked to changes in the condition and extent of ecosystem assets. The strength of applying such an accounting structure is that the information on stocks and flows can be integrated with information contained in economic accounts. This is reflected in the ability of ecosystem accounting approaches to:

- Organize information on ecosystems in a coherent manner by developing conceptual linkages between ecosystem assets and services;
- Consistently apply a common set of concepts, terminology, standards and classifications;
- Enable connections to be made to environmental/economic information compiled following the SEEA-Central Framework;
- Permit integration with the standard national accounts (as described in the System of National Accounts) to aid the measurement of the production and consumption of ecosystem services, the attribution of the degradation of ecosystems to economic activity and the recording of expenditure by economic units on the maintenance and restoration of ecosystems; and
- Identify key information requirements and information gaps.

To support this integration, ecosystem accounting involves the merging of information from the physical sciences with information on the economy and other human activity within accounting structures. The information requirements for ecosystem accounting are necessarily multi-disciplinary and build on a number of areas such as ecology, economics, geomatics, geography, social science and statistics. An accounting approach with its concepts, rules and classifications provides an appropriate way of integrating such diverse information.

Relevance of ecosystem accounting...

The general motivation for the development of SEEA-Experimental Ecosystem Accounting is the understanding that economic and other human activity are contributing to the degradation of ecosystems. Consequently, there is a reduced capacity for ecosystems to continue to provide the services upon which economic and other human activity depends.

In this context ecosystem accounting responds to a wide range of evolving demands for integrating information related to environmental sustainability and human well-being. Ecosystem accounting aims to support analysis for policy in the broad area of sustainable development, and also in areas such as landscape management, resource efficiency and energy use, water supply and use, conservation and biodiversity, environmental technologies, waste management, climate change, health and security (in terms of protection from natural hazards or continued supply).

Box 3: Canada's MEGS (Measuring Ecosystem Goods and Services) Project

In 2011, Statistics Canada received federal funding to develop prototype ecosystem accounts with the specific objective of filling policy needs related to the valuation of ecosystem goods and services. The project, MEGS, is developing the statistical infrastructure, consolidating existing data and building knowledge across the partner federal departments and agencies: Environment Canada, Natural Resources Canada, Agriculture and Agri-food Canada, Fisheries and Oceans Canada and Parks Canada. Statistics Canada also serves as the hub for a government-wide virtual community of practice and as the link with the international statistical community on ecosystem accounting.

The results from the MEGS project will be published by Statistics Canada in fall 2013. The publication will focus on ecosystem accounting concepts, on examples of national ecosystem accounts, as well as on the results of the case studies. The publication will include:

- National-level land cover maps and land cover change matrix;
- Experimental national indicators of ecosystem quality (net landscape ecological potential);
- National wetlands indicators (such as population contributing to phosphorous loads and population receiving benefits from wetland services);
- National coastal ecumene;
- Case studies on wetlands, protected areas and coastal zones.

The publication will demonstrate the results of the practical application of ecosystem accounting principles to a large country, and evaluate the extent, quality and value of ecosystem goods and services, and other ecosystem accounting principles, by looking at local case studies.

Source: Statistics Canada

Box 4: UK's experience of ecosystem accounting

The UK Government has made a commitment to fully include the value of natural capital and ecosystems into the UK Environmental Accounts by 2020, building on the results of the recent National Ecosystem Assessment. As part of the process, the UK published a consultation paper in July 2012 which set out the rationale for the accounts, provided a tentative outline timetable of development work, and sought views on the scope of the accounts and relative priorities for their development.

The consultation, which was completed in September 2012, was followed up by a stakeholder workshop in October to discuss the priorities and scope of a roadmap which will provide a more detailed timetable for the development of the accounts. The roadmap is to be published in December 2012. The workshop confirmed the importance of particular ecosystems and ecosystem services, endorsed the proposal to develop an overarching "top-down" estimate of the value of the nation's environmental capital, and identified the potential value of cross-cutting accounts such as those for carbon and water.

In addition to consulting on the roadmap, the UK has made the following progress in this area:

- Established good links with the Natural Capital Committee, which advises the government on the state of natural capital in England;
- Commissioned new research through the National Ecosystems Assessment follow-up;
- Started work on a pilot woodlands ecosystem account;
- Drafted an issues paper on the development of an account for enclosed farmland;
- Started planning work on the "top-down" estimates of natural capital.

Source: Office of National Statistics, United Kingdom. Consultation paper can be downloaded at:
`http://www.ons.gov.uk/ons/about-ons/user-engagement/consultations-and-surveys/archived-consultations/2012/accounting-for-the-value-of-nature-in-the-uk/index.html`

The structural links between ecosystem accounting and the standard economic accounts of the SNA make it possible to evaluate the extent to which ecosystems are impacted by economic activity and assess the potential for alternative patterns of consumption and production, alternative uses of energy and the extent of decoupling of growth, the effectiveness of resources spent to restore the environment, and the trade-offs between alternative uses of the environment.

4 Key concepts

Statistical units for ecosystem accounting...
While ecosystems can be thought of as areas of forest, tundra, lake, stream, grassland, wetland or agricultural land, for ecosystem accounting purposes, more precise, mutually exclusive, delineations of ecosystems in terms of spatial areas are required. To this end, SEEA-Experimental Ecosystem Accounting proposes a units model, based around spatial areas, to provide a focus for measurement and compilation. The units model consists of three different types of units: basic spatial units (BSU), land cover/ecosystem functional units (LCEU) and ecosystem accounting units (EAU).

Basic spatial units (BSU)...
A BSU is formed by partitioning the area of interest (for example a region or country), typically by overlaying a grid on a map of the relevant territory. The BSU should be as small as possible with the scale being chosen based on available information and the degree of diversity in the landscape. A grid, for example, may be the best resolution of recent satellite imagery for the country, including its freshwater and coastal areas.

Each BSU is a mutually exclusive area that can be attributed with a basic set of information, at a minimum the location of the unit and its land cover. Additional information can be added depending on the purpose of the account being compiled. This may include soil type, groundwater resources, elevation and topography, climate and rainfall, species present and their abundance, the degree of connection to related areas, current or past land uses, land ownership, location relative to human settlement, and the degree of accessibility to the area by people. A national set of BSUs, therefore, provides the basis for an ecosystem register, akin to a business register used for economic statistics.

Land cover/ecosystem functional units (LCEU)...
An LCEU is defined by areas that satisfy a pre-determined set of factors relating to the characteristics and operation of an ecosystem. Examples of these factors include land cover type, water resources, climate, altitude and soil type. A particular feature is that an LCEU should be able to be consistently differentiated from neighboring LCEUs based on ecosystem characteristics. Thus, ecological interactions within an LCEU should be stronger than between neighboring LCEUs.

LCEUs would commonly be considered as ecosystems or biomes and will vary in size depending on the situation in a given country. Thus not all countries will have all types of LCEUs. For the purposes of national level ecosystem accounting it is appropriate to consider only a limited set of LCEU classes. Various studies and reports have used different classifications but with commonly understood terms (e.g. forests, wetlands, grasslands, coastal areas). SEEA-Experimental Ecosystem Accounting proposes a provisional

Box 5: The status of environmental and ecosystem accounting in Australia

There is considerable activity in the development of environmental and ecosystem accounting in Australia. The work is building on the existing research programs in an effort to become operational, with some successes in place. The established accounts are characterised by strong cross-agency and research sector engagement. The following are some snapshots of the work and progress to date.

Completing the Picture The background work and, ultimately, the adoption of the SEEA-Central Framework as an international standard was a catalyst for the Australian Bureau of Statistics to produce the Completing the Picture publication. It presents a series of issues and maps them to a set of environmental accounts for water, energy, land cover, CO2 emissions, biodiversity and the value of natural resources to show how accounts can be used for decision-making and policy development in Australia. A reduced version of this will be produced as an annual publication. `http://www.abs.gov.au/ausstats/abs@.nsf/mf/4628.0.55.001`

Water accounts An asset account, called the Water Account is produced annually by the Bureau of Meteorology. It provides information on water stores and flows, water rights and water availability in selected major catchments across Australia. The supply and use of water by industry and households in Australia is also produced annually by the Australian Bureau of Statistics.
`http://www.bom.gov.au/water/nwa/` and `http://www.abs.gov.au/ausstats/abs@.nsf/mf/4610.0`

National Greenhouse Accounts The Department of Climate Change and Energy Efficiency is producing greenhouse gas emission accounts for greenhouse gases to meet Australia's reporting commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and track progress against Australia's target under the Kyoto Protocol as well as inform policy makers and the public.
`http://www.climatechange.gov.au/en/climate-change/emissions.aspx`

Regional Environmental Accounting Trials The Wentworth Group of Concerned Scientists, in collaboration with ten natural resource management regions, are conducting regional environmental accounting trials to assess contributions to improved environmental outcomes. The trials are testing an approach to assessing ecosystem asset condition using an innovative common currency approach that depends on scientific accreditation.
`http://www.wentworthgroup.org/recent-papers`

Experimental Land and Ecosystem Accounts The Australian Bureau of Statistics with assistance from the Queensland Government has produced accounts for the catchments draining in to the Great Barrier Reef. The Australian Bureau of Statistics with assistance from the Victoria Government is preparing a set of accounts for Victoria.
`http://www.abs.gov.au/ausstats/abs@.nsf/mf/4609.0.55.001`

An Australian Environmental Accounting Framework The Australian Government has commissioned the development of a conceptual framework to guide the implementation of environmental and ecosystem accounting into the future. Drawing strongly on the SEEA-Central Framework and Experimental Ecosystem Accounts the Framework is in draft form and undergoing extensive multi-disciplinary and multi-agency expert review. The Framework and the associated Joint Perspectives Model is expected to be released for public comment in early 2013.
`http://www.bom.gov.au/environment/activities/accounts.shtml`

Ecosystem services Work on this is advancing at national and regional levels. Nationally the Department of Agriculture, Fisheries and Forestry has a discussion paper, while at the regional level work is being advanced in the South East Queensland Catchment Management Authority.
`http://www.daff.gov.au/__data/assets/pdf_file/0020/2210591/ecosystem-final-full.pdf`

Source: Australian Bureau of Meteorology

set of LCEU classes based on the FAO Land Cover Classification System (LCCS v3) that is used in the SEEA-Central Framework.

Ecosystem accounting units (EAU)...

An EAU should represent a relatively stable area that is relevant for analysis and reporting purposes. In delineating an EAU, consideration should be given to administrative boundaries, environmental management areas, large scale natural features (e.g. river basins) and other factors relevant to defining areas for reporting purposes. Overall, EAU are likely to be large areas about which there is interest in understanding and managing change over time.

The size of EAU may vary substantially depending on the relative homogeneity of the landscape, the size of the region or country, and other related factors. Generally, an EAU will contain a number of different types of LCEU. Different EAU may be aggregated into larger units, with the largest EAU being the country level.

The development of statistical units should be undertaken in concert with the development of Geographic Information Systems (GIS) databases containing ecological information such as soil type and status, water tables, rainfall amount and pattern, temperatures, vegetation, biodiversity, slopes, altitude, etc., as well as, potentially, information on land management and use, population, and social and economic variables. This information will be relevant to the assessment of flows of ecosystem services and the condition of ecosystem assets.

5 General model of stocks and flows

As with all accounting systems, ecosystem accounting is founded on relationships between stocks and flows. In SEEA-Experimental Ecosystem Accounting, the stocks are represented by spatial areas each comprising an ecosystem asset. Each ecosystem asset has a range of characteristics – such as land cover, biodiversity, soil type, altitude and slope, etc – which describe the operation and location of the ecosystem.

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

Second, there are flows reflecting that people, through economic and other human activity, take advantage of the multitude of resources and processes that are generated by ecosystem assets – collectively these flows are known as ecosystem services. Ecosystem services are generated from the combination of ecosystem characteristics, intra-ecosystem flows and inter-ecosystem flows. Figure 1 depicts a general model of the relationships between the stocks and flows described in ecosystem accounting.

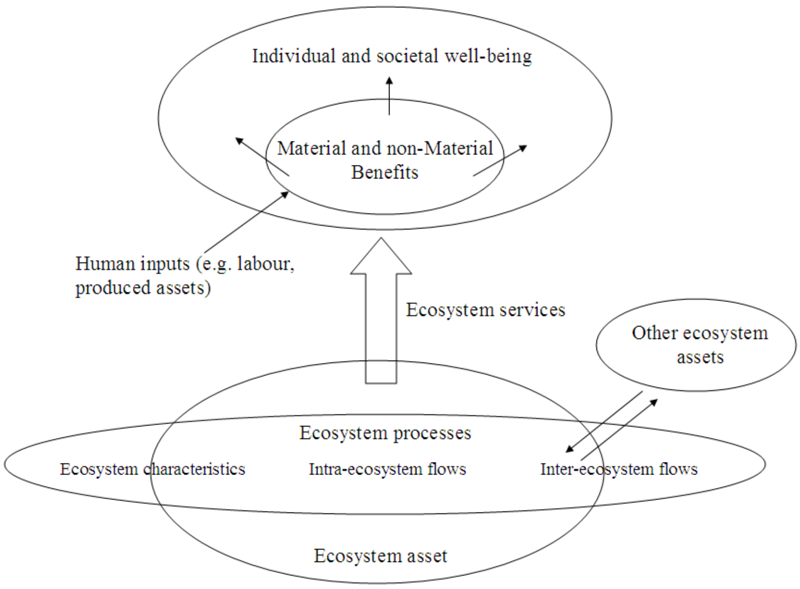
Ecosystem benefits...
The model shown in Figure 1 can be seen as a "chain" linking individual and societal well-being, benefits, ecosystem services, ecosystem processes and ecosystem assets. Starting at individual and societal well-being, the chain recognizes that well-being is influenced by the receipt of benefits. In the context of ecosystem accounting, benefits comprise:

- The products produced by economic units (e.g. food, water, clothing, shelter, recreation, etc). These are referred to as material (or SNA) benefits with the measurement boundary defined by the production boundary used to measure GDP. This includes benefits produced by households for their own consumption;
- The benefits that accrue to individuals that are not produced by economic units (e.g. clean air and water). These benefits are referred to as non-material (or non-SNA) benefits reflecting that the receipt of these benefits by individuals is not the result of an economic production process defined within the SNA. A distinguishing characteristic between these two types of benefits is that, in general, material benefits can be bought and sold on markets whereas non-material benefits cannot.

Ecosystem services...
Ecosystem services are the contributions of ecosystems to benefits used in economic and other human activity. This definition excludes some flows that are often considered ecosystem services in other contexts, in particular intra- and inter- ecosystem flows that relate to ongoing ecosystem processes, commonly referred to as supporting services. While these flows are not considered ecosystem services, they are considered as part of the measurement of ecosystem assets.

The focus in SEEA-Experimental Ecosystem Accounting is on "final" ecosystem services, that is those resources and processes of an ecosystem that contribute directly to benefits. It is these final services that have a direct link to the economy and other human activity since they are often bought and sold on the market: food crops, timber, fish and clean water, or they are consumed directly by people.

Figure 1: General model of flows related to ecosystem services



A classification of ecosystem services is important for organising and comparing information on ecosystems. A Common International Classification of Ecosystem Services (CICES) is under development to provide consistent categories for use in ecosystem accounting. At the highest level, the proposed CICES hierarchical structure recognizes three broad categories:

- Provisioning services (water, materials, energy and other provisioning services);
- Regulating services (remediation and regulation of biophysical environment, flow regulation, regulation of physico-chemical environment, regulation of biotic environment); and
- Cultural services (physical or experiential use of ecosystems, intellectual representations of ecosystems).

Ecosystem assets...

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

In general terms, the capacity of an ecosystem asset to generate a basket of ecosystem services can be understood as a function of the condition and the extent of that ecosystem. An ecosystem asset may have the potential to generate a range of different baskets of ecosystem services depending on choices made in the course of economic and other human activity. At the same time, depending on the ecosystem condition and extent, an ecosystem asset may not have the same capacity to generate different baskets, i.e. some baskets of ecosystem services may be generated over longer time periods than others.

The relationship between these two perspectives is not simple; rather it is likely to be non-linear and variable over time. Consequently, a variety of measures of ecosystem assets is needed for a complete assessment.

Ecosystem condition...

Ecosystem condition reflects the overall quality of an ecosystem asset. The assessment of ecosystem condition involves two distinct stages of measurement with reference to both the quantity and quality aspects of the characteristics of the ecosystem asset. In the first stage, scientific research should guide the selection of characteristics and associated indicators of change that permit assessment of the ongoing functionality and integrity of the ecosystem asset. The selection of characteristics and indicators should be made on scientific basis such that there is assessment of the ongoing functionality and integrity of the ecosystem asset.

Measures of ecosystem condition are generally compiled in relation to key ecosystem characteristics (e.g. water, soil, carbon, vegetation, biodiversity) and the choice of characteristics will generally vary depending on the type of ecosystem asset. Further, the selection of characteristics should take into account current and expected future uses of the ecosystem, (e.g. for agriculture, forestry, carbon sequestration, recreation, etc) since these uses are likely to impact most directly on certain characteristics and hence on the

Table 1: CICES for the SEEA-Experimental Ecosystem Accounts

Section(1-digit)	Division(2-digit)	Group(3-digit)
Provisioning	Water	Water
	Materials	Uncultivated terrestrial plants and animals for food
		Uncultivated freshwater plants and animals for food
		Uncultivated marine plants, algae and animals for food
		Nutrients and natural feed for cultivated biological resources
		Plant and animal fibres and structures
		Chemicals from plants and animals
		Genetic materials
	Energy	Biomass based energy
	Other provisioning services	Other provisioning services, n.e.c.
Regulating	Remediation and regulation of biophysical environment	Bioremediation
		Dilution, filtration and sequestration of pollutants
	Flow regulation	Air flow regulation
		Water flow regulation
		Mass flow regulation
	Regulation of physico-chemical environment	Atmospheric regulation
		Water cycle regulation
		Pedogenesis and soil cycle regulation
		Noise regulation
	Regulation of biotic environment	Lifecycle maintenance, habitat and gene pool protection
		Pest and disease control (incl. invasive alien species)
Cultural	Physical or experiential use of ecosystems [environmental setting]	Non-extractive recreation
		Information and knowledge
	Intellectual representations of ecosystems [of environmental settings]	Spiritual and symbolic
		Non-use

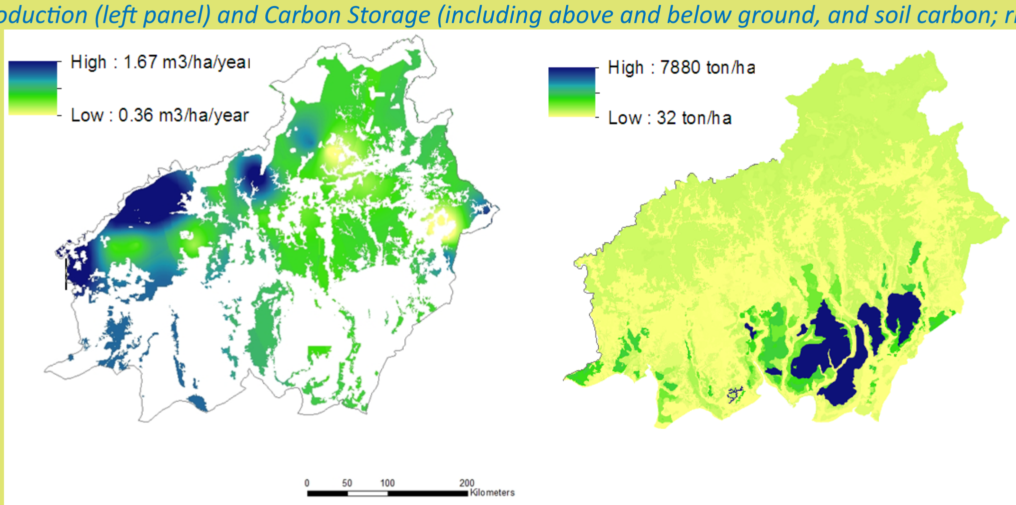
Box 6: The Wageningen University 'Ecospace' Project in Indonesia, Netherlands and Norway

The objective of this project is to test and develop new spatial methods for the physical and monetary analysis of ecosystem service flows and assets, on a provincial scale. The project follows the overall principles of ecosystem accounting and is implemented in three provinces in Indonesia, the Netherlands and Norway, with collaborating partners in both Norway and Indonesia. The project started on 1 November 2010 and will lead to a series of publications in 2013 and 2014. The project is funded by the European Research Council (G. Ag. 263027). The project has tested and applied several spatial tools for mapping ecosystem services including Look-up tables, Geostatistics (including kriging), Maxent and various spatial regression models. Ecosystem services were analysed with different datasets and methods in order to better understand the reliability of different mapping approaches.

In Indonesia, Ecospace is implemented in the province of Central Kalimantan (around 154,000 km2), analyzing the services of timber production, rice production, rattan production, palm oil production, carbon sequestration, carbon storage, eco-tourism, and orangutan habitat. Project collaborators include a number of local and national stakeholders including Palangka Raya University, the Provincial and District authorities, the Provincial Forest and Planning Agencies, research organisations and NGOs. Data are collected from a wide range of sources including scientific literature and information from the various stakeholders, and results of the project are frequently shared with these stakeholders.

Currently, services have been analysed in physical terms (see fig. below for example). The highest carbon values are found in the peatlands. Based on collected data, ecosystem asset maps and monetary value maps are being prepared.

Timber production (left panel) and Carbon Storage (including above and below ground, and soil carbon; right panel)



Source: The Wageningen University 'Ecospace' Project

overall condition and capacity of the ecosystem asset to generate alternative baskets of ecosystem services. Usually, there will not be a single indicator for assessing the quality of a single characteristic.

In the second stage, the indicators are related to a common reference condition. There are a number of conceptual alternatives to determine a reference condition. The use of a common reference condition for all indicators within an ecosystem may allow an overall assessment of the condition of the ecosystem asset.

Ecosystem extent...

Ecosystem extent reflects the size of an ecosystem asset, generally considered in terms of area, e.g. hectares. Changes in the mix of different land cover within a defined spatial area may be important indicators of changes in ecosystem assets.

Expected ecosystem service flows...

Expected ecosystem service flow is a measure of all future ecosystem service flows from an ecosystem asset for a given basket of ecosystem services. The expected flows must be based on an expected basket of provisioning, regulating and cultural services from an ecosystem asset. Generally, for accounting purposes the basket of ecosystem services would be based on current patterns of use.

Because the generation of some ecosystem services involves the extraction and harvest of resources, and since ecosystems have the potential to regenerate, it is necessary to form expectations on the amount of extraction and the amount of regeneration that will take place, and on the overall sustainability of human activity in the ecosystem. To form these expectations information concerning likely changes in ecosystem condition is required.

Measuring degradation and enhancement...

Measures of ecosystem condition and extent, and measures of expected ecosystem services flows are all stock measures at a point of time. In accounting, they are most commonly measured at the beginning and end of the accounting period. Often however, there is greater interest in measuring changes in ecosystem assets, particularly ecosystem degradation and ecosystem enhancement.

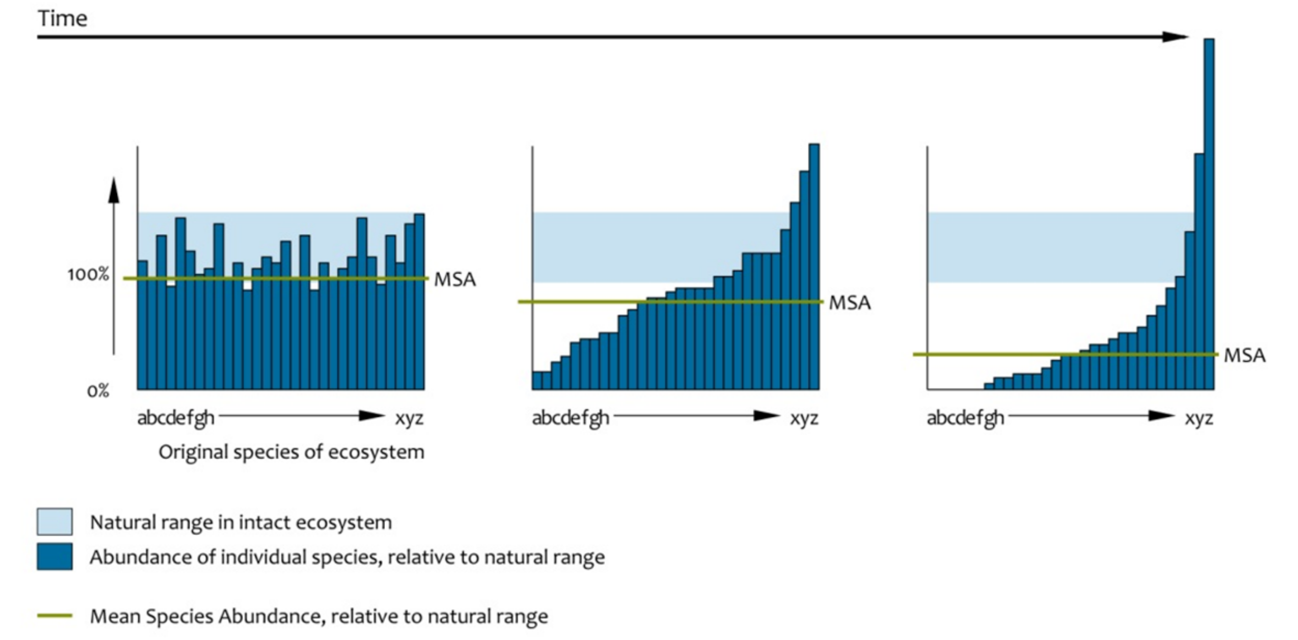
Box 7: Mean species abundance as a generic metric of biodiversity in the SEEA-Experimental Ecosystem Accounting

Biodiversity is a broad and complex concept that often leads to misunderstandings. According to the Convention on Biological Diversity (CBD), biodiversity encompasses the overall variety found in the living world and includes the variation in genes, species and ecosystems. For the purpose of SEEA Experimental Ecosystem Accounting the focus is on species, considering the variety of plant and animal species in a certain area and their population sizes. Population size is the number of individuals per species, generally expressed as the abundance of a species or briefly "species abundance".

The various nature types or "biomes" in the world vary greatly in the number of species, their species composition and their species abundance. A tropical rain forest is different from a tundra or tidal mudflat. The current loss of biodiversity is one of the unintended consequences of increased human activity. The process of biodiversity loss is generally characterised by the decrease in abundance of many original species and the increase in abundance of a few other opportunistic species.

The decrease in abundance for a species might lead to extinctions which is just the last step in a long degradation process. Countless local extinctions ("extirpations") precede the potentially final global extinction. As a result, many different ecosystem types are becoming more and more alike, the so-called homogenisation process. Decreasing populations are as much a signal of biodiversity loss as highly expanding species, which may sometimes even become plagues in terms of invasions and infestations (figure below shows this process from left to right).

Process of biodiversity homogenisation expressed by the MSA indicator



Note: The change in the abundance of original species (a-z) compared to the baseline state (as %) in an undisturbed ecosystem (left), intermediate (middle) and highly disturbed ecosystem (right). As a result, the mean species abundance decreases from 100% to 80% and 30%, respectively.

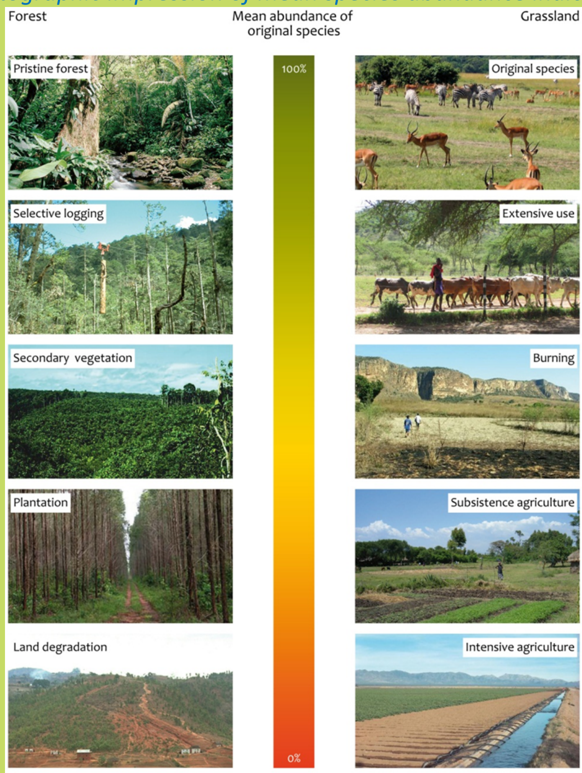
Until recently, it was difficult to measure the process of biodiversity loss. "Species richness" appeared to be an insufficient indicator. First, it is hard to monitor the number of species in an area, but more important it may sometimes increase as original species are gradually replaced by new human-favoured species, the so called 'intermediate disturbance diversity peak'. Consequently the CBD (VII/30) has chosen a limited set of indicators for use, including the "change in abundance and distribution of selected species", to track this degradation process. This indicator can be measured and modeled with relative ease, and is applicable on every scale and for every ecosystem.

The state and trends in biodiversity can be calculated in terms of the mean species abundance of the original species (MSA) compared to the natural or low-impacted state. If the indicator is 100%, the species populations have a similar size as the natural or low-impacted state. If the indicator is 50%, the average abundance of the original species is 50% of the natural or low-impacted state and so on. To avoid masking, significant increased populations of original species are truncated at 100%, although they should actually have a negative score. Exotic or invasive species are not part of the indicator, but their impact is represented by the decrease in the abundance of the original species they replace. The mean species abundance (MSA) of a country is the area weighted mean of the MSA values of the underlying constituent ecosystem types, in which each square kilometer is equally weighted. (Continues on the next page)

Box 7: Mean species abundance as a generic metric of biodiversity in the SEEA Experimental Ecosystem Accounting (cont.)

MSA can be calculated for any scale: basic spatial unit, ecosystem accounting unit, a biome, country or the whole world. It can be monitored, but in case of lack of monitoring data it can be simply and cheaply modeled instead. MSA has been applied in various countries and various regional and global assessments such as those from UNEP, OECD and the CBD (more details can be found at `www.globio.info`). The Living Planet Index, Biodiversity Intactness Index, the Natural Capital Index and the Nature Index are basically the same.

Photographic impression of mean species abundance indicator



Note: Visual impression of the mean species abundance scale for forest and grassland in different stages of disturbance (100% - 0%).

Source: PBL Netherlands Environmental Assessment Agency

A key indicator of change in ecosystem assets is ecosystem degradation which is the decline in an ecosystem asset over an accounting period. Generally it will be reflected in declines in ecosystem condition and/or declines in expected ecosystem service flows. Ecosystem enhancement is the improvement in an ecosystem asset that is due to economic and other human activity and reflects activities to restore or remediate an ecosystem asset beyond activities that may simply maintain an ecosystem asset. Following the logic of the asset accounts described in the SEEA-Central Framework, accounting entries may be defined which reflect the different changes to ecosystem assets over the course of an accounting period.

Human intervention in ecosystems can have small or large impacts on ecosystem assets. Minor changes may occur, for example, if trees are selectively harvested from a forest. Human intervention may also lead to an ecosystem changing completely (e.g. from forest to agricultural land as a result of land clearing). On the other hand, human intervention may improve ecosystem assets by restoring ecosystem functions through conservation and protection activity. These different changes should be distinguished within an ecosystem asset account.

6 Physical and monetary measures

The accounting framework described in SEEA-Experimental Ecosystem Accounting provides means of organizing information in both physical and monetary terms. Information in physical terms includes data recorded in physical units of measure (hectares, kilograms, liters, parts per million, etc.) as well as data relating to experiential services (e.g. number of visitors to a cultural site). In this regard the expression “physical terms” is used to refer to information that is recorded in non-monetary terms.

Physical measures...
The scope of information that may be included in physical terms is very broad. While the accounting approach is suitable to organize this information, because the separate pieces of information are in different measurement units, the aggregation of information is a challenging exercise. A number of approaches to aggregation have been developed, including the use of common ”currencies” (e.g. hectares) and composite indexes, but all require the use of assumptions concerning the relative importance of different indicators. Further research is needed to develop and test the relevant methods and assumptions.

Monetary measures...
SEEA-Experimental Ecosystem Accounting also discusses the estimation of accounting measures in monetary terms. This requires the valuation of ecosystem services and ecosystem assets. Since ecosystem services and ecosystem assets are not typically traded on markets, observed prices cannot be used to measure these assets and services as in standard economic accounting. This is true even where there are monetary transactions associated with the benefits obtained from the use of ecosystem services. For example, the value of sales of landed fish cannot be used directly to estimate the value of ecosystem services since it incorporates the contributions (as input costs) of labour and produced assets of the fishing activities, in addition to the contribution of the ecosystem services such as primary production, habitat availability and the growth of the fish themselves.

Valuation...
Ecosystem accounting therefore requires the use of various approaches to valuing non-monetary transactions. Many such approaches have been developed. However, often the use of these approaches does not recognise the distinction between welfare values (which are relevant in the context of assessing public policy options) and exchange values (that are required for accounting purposes). Since the focus of ecosystem accounting is generally on integration with the standard economic accounts, it is important that the valuation approaches that are used reflect exchange values.

Generally, it is necessary to be specific about the purpose and scope of valuation. There are also important considerations regarding the valuation of ecosystem services and ecosystem assets that should be recognised before developing ecosystem accounting in monetary terms. For example, the valuation of different ecosystem services may require the use of different approaches; it may be difficult to aggregate from site specific values to ecosystem wide estimates; and there are likely to be various uncertainties concerning the dynamics of ecosystems and future flows. How to value ecosystem assets and ecosystem services in a robust way that is consistent with national accounting valuations is a significant issue for future research in ecosystem accounting.

Combined presentations...
One approach to considering information on ecosystems in physical terms and economic information in monetary terms is the development of combined presentations. These presentations use consistent approaches to classification to show information in physical and monetary terms at the same time. An example of a combined presentation is one comparing expenditures on environmental protection in monetary terms and changes in ecosystem condition in physical terms.

7 The way forward

Institutional arrangements...
Placing ecosystems in an accounting context that can be integrated with economic accounts requires the central disciplines – ecology, economics and national accounting – to consider measurement in new ways.

- For ecologists, this requires creating clear distinctions between ecosystem assets and ecosystem service flows and to differentiate between those aspects of ecosystems that provide direct benefits to economic and other human activity and those aspects of ecosystems that, effectively, support the provision of these benefits.
- For economists, it is necessary to consider their conceptual models concerning the links between ecosystems and the economy in a strict accounting sense, and to consider the complexities of integrating new measures of ecosystem assets and services with traditional economic measures.
- For national accountants, it is necessary to consider the set of goods and services produced and consumed in the context of the set of benefits provided by ecosystems and also to see the ecosystem as a complex, self-regulating system that, while influenced by economic activity, also operates outside of traditional economic management regimes.

Central to the successful advancement of ecosystem accounting is the involvement of a wide range of professional communities, since a single agency or organization cannot effectively cover all of the information requirements for a set of ecosystem accounts. This is particularly the case for the range of biophysical information which may be localized in specific institutions.

Consequently, the development and testing of ecosystem accounting will require the involvement of multiple disciplines across agencies. The types of agencies that are likely to be involved include national statistical offices (NSO); government scientific and meteorological agencies; departments of environment, agriculture, forestry and fishing; and government geographical and geo-spatial information agencies. The establishment of appropriate institutional coordination and management arrangements is essential if the work is to be routinely implemented. Further, given the emerging presence of ecosystem accounting, there is strong potential to harness the research capability of academia to develop and test aspects of proposed ecosystem accounting framework.

Particular note is made of the potential role of NSOs in supporting efforts in ecosystem accounting. Their traditional skills in organizing large, diverse and complex data sets, using standard definitions and classifications, providing coherent national-level pictures, and applying data quality standards, are all significant, complementary skills that are relevant in ecosystem accounting.

Scientists, economists and statisticians will continue to improve their understanding of how ecosystems function and how analytical and measurement techniques may be adapted. The synthesis of current knowledge presented in SEEA Experimental Ecosystem Accounting aims to support the ongoing improvement in understanding and contribute to the integration of information on ecosystems into decision making processes.

For further information on this note, contact seea@un.org.